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PUBLISHER
Don Shay

EDITOR
Jody Duncan

ASSOCIATE EDITOR
Joe Fordham

ASSISTANT EDITOR
Estelle Shay

DESIGN CONSULTANT
Michael Gross

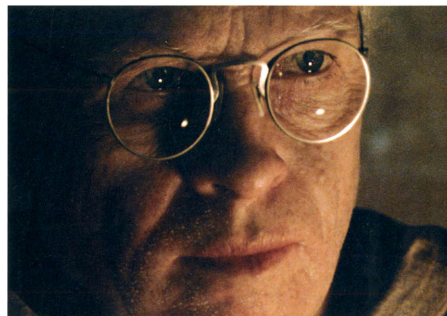
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ADVERTISING REPRESENTATIVES
Bernice Briggs
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PRODUCTION MANAGER
Marge Duncan

WEBMASTER
Gregg Shay

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Countdown to Doomsday

ARTICLE BY JOE FORDHAM

Nuclear apocalypse and dwindling energy resources  have rarely been topics for children's literature, but novelist Jeanne DuPrau combined both in a series of speculative adventure novels, the first of which was published in 2003 and filmed as *City of Ember*.

The Walden Media picture began development in 2004 when Playtone, the production company owned by actor Tom Hanks and producer Gary Goetzman, optioned DuPrau's novel and commissioned screenwriter Caroline Thompson and director Gil Kenan to adapt the story. Set in Ember, a 240-year-old subterranean city where generations have been raised with no knowledge of the outside world, the narrative was told from the point of view of Lina Mayfleet (Saoirse Ronan), an imaginative young orphan who discovers clues to a world and a civilization beyond her own. Lina teams up with a young engineer, Doon Harrow (Harry Treadaway), to plot against a corrupt mayor (Bill Murray) and escape their aging city's technological collapse.

Gil Kenan's involvement began in the production's early stages, before his feature debut, the performance-capture CG feature *Monster House*. Despite his background in animation, Kenan envisioned *City of Ember* as a live-action movie, which posed the challenge of finding a soundstage large enough to contain a city. After investigating stages in Romania, Berlin and England, the production chose a base of operations in Northern Ireland that had never before been used as a filming location.

The Harland & Wolff painting facility in Belfast's docklands was a cavernous structure that had once housed the R.M.S. *Titanic*. The building contained a grid of four halls — each 130-foot square, with 95-foot-high ceilings — and required an extensive shakedown to convert it into a soundstage. "Each individual hall wasn't big enough to hold the whole of the city of Ember," explained special effects supervisor Kit West, "but the local council dug out the original plans, and engineers from the Harland & Wolff dockyards told us that with a certain amount of jackhammers and shoring up we could cut large holes through the walls so that we could build sections of the city in different paint halls, using roadways and arches to disguise where we connected one hall to another."

The production also cut into the building's six-foot-thick concrete floor to plumb the set with running water, and installed a gantry for lighting and access above the studio floor. While the construction department built Ember sets, Kit West and special effects floor supervisor Terry Glass set up a base of operations in an auxiliary workshop built on the slipway that once launched the *Titanic*, and crewed up with engineers, electricians, carpenters and welders recruited from the local welding and boilermakers' union.

Gil Kenan meanwhile developed storyboards and 3D animatics to design action sequences and visual effects, which laid the foundation for shot designs when visual effects supervisor Eric Durst joined the team. "Gil conceived a lot of shots in an animated format and then matched live-action to that," Durst recalled. "The previz was never intended to be used as final rendered animation, but

Gil used those tools to work out timings and choreography of shots. My background is animation, like Gil, and it was very helpful to be able to communicate with him in those terms.”

Durst assigned visual effects to six vendors. Luma Pictures handled approximately 100 shots, including creature effects and digital set extensions to subterranean levels of Ember — known as the ‘pipeworks’ — and an underground river ride. BUF Compagnie handled 39 shots, comprising nearly eight minutes’ screen time, including Ember set extensions and additional creature work. Filmworks/FX, Amalgamated Pixels, Zen Haven and Below the Radar handled additional work, including editorial effects, composites and digital matte paintings.

Ember’s history is revealed in the opening shots of the film, in which the city’s founders seal a metallic time-capsule box containing instructions for returning to the world above in 200 years, and a succession of mayors pass the box from generation to generation in an impressionistic montage. Eric Durst and BUF filmed a series of actors using motion control supplied by Motion Control Cameras. “The camera and box were on independent motion control tracks,” explained BUF visual effects supervisor Olivier Cauwet. “Each actor passed the box between their hands, giving the box to the next mayor. A motion control operator controlled the movement of the box, moving it along and making the box roll and tilt as the camera followed it. We recorded that data and shot repeat passes, using a video mixer to match finger positions of older actors to younger actors’ hands on the box. In postproduction, we then morphed from the younger to the older hands, so the mayors appeared to age.”

BUF integrated digital time code and damage onto the box as the 200 years tick by. The box is finally lost and laid to rest inside a closet, where BUF created a time-lapse transition using a 3D reconstruction of the closet floor. The camera then moved into the box as the lid popped open, engulfing the camera lens, until the main title appears, animated by BUF in the filament of an electric lamp.

The camera descends from the lamp to reveal a grid of lights strung above Ember. Gil Kenan shot the scene as a Technocrane move that descended into the city set, which the production built to just below the roof of the foreground buildings, with studio lights, scaffolding and black duvetyne backdrop visible in the background.

The lighting grid was an entirely digital creation by BUF. “Production designer Martin Laing provided us with drawings to give the atmosphere and the main idea of the city of Ember,” said Olivier Cauwet. “We translated that into a 3D model, refining details with Eric and Gil about the atmosphere, lighting rig height and intensity of the lights. We used dynamic simulations to create sagging in wires between different levels of lamps, so everything appeared to be aged. We controlled the brightness of each lamp; so, for each shot, Gil could make it brighter or dimmer to optimize each composition.”



Adapted from a novel by Jeanne DuPrau, City of Ember was set in an underground city whose citizens live unaware of the nuclear war that destroyed civilization above ground more than 200 years ago. Director Gil Kenan and production designer Martin Laing created a large portion of the city inside a disused ocean liner painting facility in Belfast, Northern Ireland. Special effects supervisor Kit West supplied physical effects, while visual effects supervisor Eric Durst furnished digital

BUF rendered the lighting grid with smoke and 3D atmospheric effects, and tracked in digital set extensions of the city. “The city resembled a European village,” related Eric Durst. “It was about 500 yards wide, and technology was in a Jules Verne style, with large gears that drove mechanisms, which all played a part in Lina and Doon’s escape.”

enhancements, including city extensions created at BUF Compagnie and lower-level subterranean enhancements by Luma Pictures.

Seen from above, the city resembled a circular antique clock face created out of a chaotic jumble of buildings. BUF modeled 3D buildings using blueprints and photographic surveys of sets. “We built some basic building shapes,” stated Olivier Cauwet. “We used those to build backgrounds and detailed closer structures depending on the proximity to camera. We added props in the street and on the roofs to create a sense of history. We aged the buildings and added smoke, atmospheric haze and light emissions. We created CG people in the streets from photos of extras in costume on set, and used our database at BUF to model them and add animation of people walking and talking with each other.”

The crane shot was originally conceived as an introduction to Lina, but was reconfigured to, instead, come to rest at a foreground building revealing Doon and his father Loris (Tim Robbins) inside. Gil Kenan shot the interior as a pickup during postproduction at Rosarito Studios, in Mexico. Amalgamated Pixels tracked the element into the foreground of the crane shot, integrating the interior into a digital façade of Loris Harrow’s repair shop.

A few scenes later, the tail end of the crane shot resumes, following Lina exiting her grandmother’s home, descending a staircase, and hurrying down a street in what appears to be one unbroken take. “Lina running down the stairs was a Techocrane move,” revealed Eric Durst. “As she went down the street, that transitioned to a Steadicam move. We shot those two camera setups next to each other, hoping they would line up. Fortunately, the atmosphere in both the A and B takes matched perfectly, and then BUF stitched the shots together.”



Lina Mayfleet (Saoirse Ronan), a young girl who discovers clues to her city's origins, pauses in front of the Ember town hall before delivering a message to the mayor (Bill Murray). The production built Ember in the Belfast facility by burrowing through internal walls in the paint hall structure, and designed roadways and arches to connect portions of the set. Structures extended three stories tall, which allowed Gil Kenan to compose many shots within the practical set. Digital set extensions finished off angles that revealed studio lights, scaffolding and large sheets of black duvetyn beyond the set.

BUF linked the shots using a subtle morph and 3D background tweak. “We could see the transition was working as a simple cut,” observed Olivier Cauwet. “We rotoscoped Lina from the shot and morphed, blending her from one take to another, so she left one take as she jumped and transitioned to another as she landed. We then adjusted the background using texture projection onto geometry of the street and created a camera move in 3D.” Composited back into the plate, Lina appeared to seamlessly run from crane shot to fluid tracking shot, where the camera chased along behind her until it revealed a glimpse of the lighting grid above, which BUF tracked into an upper quadrant of the shot.



The production used previzualization to guide the creation of digital set extensions, which included the addition of an expansive grid of lamps and electrical cables strung above the city to provide Ember citizens a facsimile of daylight. BUF Compagnie accompanied the shoot to gather survey data and high dynamic range reference images of the set, then generated city set extensions and the lighting grid digitally. BUF used dynamic simulations to make wires between lamps sag, as if with age, and controlled the brightness of each lamp, creating effects of irregular brightness across the decrepit lighting grid.

Special effects technicians created atmospheric diffusion throughout the city by using carefully monitored levels of smoke oil. “I had six technicians every day controlling the flow of smoke,” Kit West recalled. “It was tricky because we would get it to a certain level for the camera looking one way; but then, when they changed the angle, that same level, lit differently, appeared to change — even though we had exactly the same amount of haze as we had before. We were constantly pumping smoke up and down, and blowing it around with fans.” The visual effects crew shot plates requiring digital set extensions with smoke, using tracking markers and high dynamic range image surveys on set. BUF then employed combinations of 2D and 3D digital matte painting to render layers of buildings, street lamps and matching atmospheric effects.

The city’s outer reaches are depicted in a scene in which Lina visits the city’s greenhouses, where horticulturalists tend crops in hangars strung with fluorescent lamps. The production filmed greenhouse scenes on a disused volleyball court inside Maysfield Leisure Center in Belfast. The set contained one complete hangar, a portion of another and an expanse of trash heaps backed by duvetyn. BUF added Ember and its lighting grid to the sequence as Lina is seen running from the city. “Eric shot Saoirse running past a greenscreen with only the floor built as a set,” said Olivier Cauwet. “She ran toward camera, and then the camera started to pan. They then shot the other way, with Lina running from camera toward the greenhouse. We tracked the two shots in 3D and stitched them together with a 3D camera move matched to the camera movement in the first plate. We added the city behind Lina and then followed her as she ran toward the greenhouse. It was a clever way to create a sense of distance in the shot.”

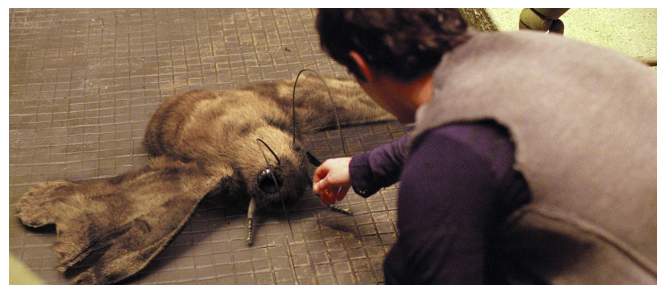
Pipeworks scenes below the city were filmed in a labyrinth of tunnels constructed in the paint halls, rigged with extensive floor effects. “We had to bring the whole underworld to life,” remarked Kit West. “We worked very closely with set dresser Celia Bobak to fit all of the pipeworks with escaping gas and steam. Once the sets were designed, we installed a giant steam machine in each paint hall. We fed smaller pipes through larger set-dressing pipes and piped in CO2 and liquid nitrogen and, where characters had to walk through escaping gas, we used quick-dispersing smoke oil. We

controlled everything on solenoids, and our operators could vent it out, making pipes appear to burst every now and again.”

Doon infiltrates a restricted area in the pipeworks where he witnesses the city’s internal workings in chaos inside the generator room. The production constructed the generator room as a central bridge linking a doorway and the lower portion of the generator, flanked by oversized voltage transformers backed by greenscreen. Luma Pictures lead environment artist Chris Sage oversaw construction of digital set extensions for the chamber, which is seen in a sequence in which Doon first discovers the machine, and is also heavily featured in the third act of the film. “The ceiling of the generator room was supposed to be 300 feet tall,” commented Luma visual effects producer Steve Swanson. “The generator took up two-thirds of the distance from the floor, making it about 250 feet in real-world scale. The first generator room scene with Doon became a ‘kitchen sink’ shot for us because so much went into it. It involved three plates — Doon’s entry, a pan away to a section of the set that we extended, and then a pan back to Doon. We stitched those together with a hand-off from the practical camera track to a CG-animated move up and down the generator, and then panned back to Doon again. We had a matte-painted background of the cavern, a full 3D model of the generator with lighting, sparks, falling debris, workers filmed on greenscreen standing on struts attached to the generator, a CG water wheel below — a lot went into that environment!”

Luma attended the generator room shoot with Eric Durst and shot photographic surveys of the set. Kit West’s team provided venting steam and pyrotechnic effects of fire erupting over forms representing the generator shape. Luma then referenced production designs to construct a detailed 3D generator model bathed in a wash of red emergency lights. “The art direction was just beautiful,” remarked Luma executive visual effects supervisor Payam Shohadai. “It had enormous amounts of detail, and the shot required us to model it to a point where 85 percent of the room contained hero assets, seen close to camera with texture and shader work depicting corrosion of the metal surfaces. Gil wanted the scene covered with red light, so we planned a very careful balance of red and white fill-light bouncing across the model to bring out the detail. Gil always referred to the generator as the heart of the city, and it was falling apart and leaking oil, as if the city’s heart was malfunctioning.”

Power outages caused by the ailing generator intermittently plunge residents of Ember into darkness, achieved in-camera by director of photography Xavier Pérez Grobet, and in postproduction by visual effects. “We set up the peril early in the film,” remarked Eric Durst. “We added a number of digital flickering light effects, some lights exploding and Das Boot-style rumbling sounds. We had a few scenes that briefly went to black, but that was tightened up in editing and Gil retained enough ambient light to see what was going on. We decided it was enough to suggest the precariousness of the situation, where at any moment power could go off and that would be it.”



Doon Harrow (Harry Treadaway), a young engineer with an interest in entomology, tends to an injured moth that he discovers in a disused fountain. Giant creatures were an addition to the story, inspired by a passing reference in DuPrau’s book, designed to imply the effects of mutation caused by two centuries of irradiated evolution. Eric Durst filmed the scene using a gray-painted form to represent the moth. BUF then modeled a digital moth with an articulated body, wings, legs, antennae and fur, and

Ember residents make use of dwindling resources by recycling supplies, as seen in the Harrow household, where Doon's father has an array of Rube Goldberg

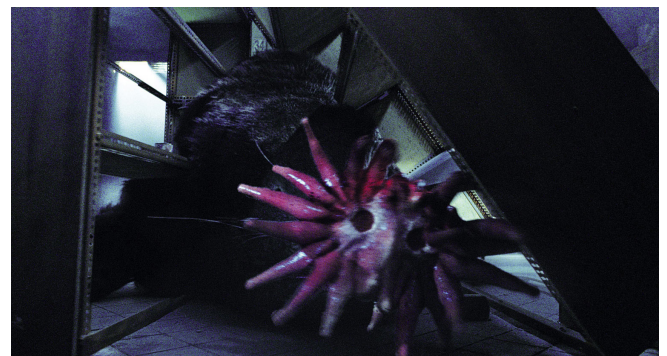
gadgets, designed by Martin Laing and created by the special effects team. "We made anything that moved in Loris' workshop," remarked Kit West. "That included robots, which had to appear to be made from scrap, as if they had been used for something else in a previous life." West's team used an air conditioner for a robot named 'Topsy' that trundled about Ember streets with an eccentric gait, and built a clumsy domestic 'Housebot' for Loris Harrow's home. "Housebot was based on a hot water boiler. We found a real boiler, bashed it around to the director's satisfaction, and then took a cast of it and made it in fiberglass. It's no good having metal casings because that can cause problems with the radio control signals getting to the mechanisms. One of my technicians, Ron Hone, had worked on R2-D2 in three *Star Wars* pictures, so he had tremendous experience with radio-controlled robots. He built six or seven different robots for us."

Ember is also home to large irradiated creatures that inhabit the darkness beyond the city. In an early scene, Doon encounters an injured moth the size of a small dog. Gil Kenan filmed the scene with Harry Treadaway reacting to a gray-painted form representing the oversized insect. BUF then replaced the shape with a 3D animated creature, designed to evoke the audience's sympathy. "We wanted the moth to feel like a puppy dog that had been wounded," said Eric Durst. "We gave it a damaged wing that Doon stitches back up, and BUF did a wonderful job on the animation." BUF modeled the moth with an articulated body, wings, legs and antennae and developed a custom fur shader to texture the creature with silky fur. The moth model was used in profusion for angles of the creatures fluttering around the lighting grid.

A more intimidating creature appears later when Doon and Lina sneak into the pipeworks and are cornered by a giant predatory rodent the size of a compact car. "We based the creature on a star-nosed mole," said Durst. "In real life, it is only a couple of inches long and its nose is a fantastic device, full of sensors that enable it to 'see' its way through touch." Durst briefly considered shooting a live star-nosed mole to digitally composite with the live-action, but deemed the idea impractical. "The mole moved so fast, we would have had to use high-speed cameras to slow it down, and we would have probably fried several of the poor creatures with the amount of light it would have required to shoot. So we made some sketches, and then Luma adapted it and animated one about seven feet long."

To shoot scenes of the giant rodent in the pipeworks tunnels and crashing through a storeroom, Gil Kenan used a 'stuffy' creature model to block out shots. Effects technicians rigged shelves to collapse, simulating creature interactions. Luma

animated the creature to evoke the impression of an injured puppy.



A more fearsome creature, a giant star-nosed mole, attacks Doon and Lina in a storeroom below the city. The production studied nature reference of the rodent, which in real life measures only a few inches in length. Gil Kenan made use of a dark furred mole form to block out shots on set, and Kit West's team supplied practical interactive effects of toppling shelves. Luma Pictures then created a digital model of the seven-foot-long rodent with a fleshy proboscis, simulations of muscle, skin, fat and fur, and dynamic simulations of storeroom interactions.

photographed HDRI studies of the set and used reference of a star-nosed mole photographed from a frozen specimen. Creature artists then modeled and rigged the giant creature to emphasize its bulk. “CG creatures are traditionally done using simulations to create muscle deformation, fat and skin bunching,” observed Luma visual effects supervisor Vincent Cirelli. “The mole was such a complex character, we wanted to avoid countless simulations on every shot, so we created two mole models: a rigid version that had no skin bunching, and a fat creature that when simulated looked like a pillow sack filled with lard. This allowed us to run the simulation once per shot and then blend between the two models, painting zones on its surface to indicate where we wanted wrinkles, and where the skin should stretch and bunch. This greatly reduced simulation time, and gave us incredible control over the dynamics of his skin.”

Luma animation supervisor Raphael Pimentel integrated the creature into shots with close attention to the animal’s startling proboscis, which resembled a highly dexterous fleshy pink anemone, preceding the bulkier shambling body. Digital effects supervisor Justin Johnson’s team rendered a dark and oily fur simulation, often played in shadow or rim-lit to emphasize the creature’s weight, and then gave the proboscis a clammy look using subsurface texture maps, lighting maps and drool. Shots of the rodent bursting up through a floor involved the keyframe-animated creature composited with dynamic simulations of smashing timbers, flying bottles, boxes and debris.

Lina and Doon escape Ember with Lina’s young sister, Poppy (Amy and Catherine Quinn), during the Day of Singing, when the inhabitants of Ember gather in Harken Square to chant songs in front of the mayor’s residence. The production filmed the event with 300 extras portraying Ember citizens, and used motion control to capture repeat passes of the crowd grouped in multiple positions in the city set. BUF created digital split-screens and multiplied the crowd in composites, dividing the screen at a central fountain.

The way out leads to a locker room where Doon discovers a hidden mechanism that moves small wooden boats across a recessed track in the floor to an adjoining chamber. The special effects crew spent several months engineering the boat delivery system using mechanisms beneath the elevated set. “It was one of our major engineering tasks,” said Kit West. “The locker had to lower itself from the wall. Then it stood upright and traveled across the room in a straight line to a roundabout that turned it around and sent it down another corridor. We rigged a motor-driven chain mechanism under the floor that pushed the boat along the straight track onto the roundabout. The roundabout then rotated it to the next section, where another chain under the set picked it up and carried it out the door.”



Doon enters Ember's vast generator room where a subterranean river drives the turbines that power the city's electrical system. The production built a portion of the generator on its Belfast soundstage, including the entry, a connecting bridge and a portion of the base of the machine backed by greenscreen. Luma Pictures created digital generator extensions and combined them with live-action elements of Doon's entry. Kit West's team supplied interactive pyrotechnic effects, which Luma then composited with greenscreen workers on platforms and myriad other details that brought the generator room to life.

Once the boat passed through a mechanical door, it emerged into the generator room, angled down a ramp to a launch point off a bridge. Kit West's team rigged the descending boat with a sliding weight mechanism. As the boat rolled forward to a fulcrum point, the weight slid forward and tipped the boat down the slope. A wire controlled the boat's descent to another motorized roundabout, which rotated the boat and propelled it down a launch ramp.

The production filmed the scene with greenscreen backing the set and lining the dry river channel. Luma then created generator room extensions, including large rotating turbines at each end of the set, giant pumping machinery inside the generator, and a luminescent backlit river flowing down the center of the chamber. "The original plan was to build water wheels and the river for real," explained Eric Durst. "They were going to have real water flowing underneath the bridge, but the shooting schedule was really tight, and we decided to do all the river with CG, with some practical splashes."

To create practical water effects, Kit West's team installed a 92,500-gallon water tank outside the set, on the *Titanic* slipway. Water pumps passed water through heaters, maintaining water temperature at approximately 75 degrees, and then re-circulated water back to the holding tank through filters. "Gil didn't want fresh-colored water," remarked West. "We used a brown dye made from peat imported from Germany that is used in beauty salon mud baths. It's called Moorlauger, and is a very pure water-soluble substance, so anybody who got covered in it would not be in any trouble with it getting in their eyes."

The effects team pumped colored water in high-pressure explosions for the shots of *Ember's* water system erupting up through the disused fountain in Harken Square. The eruption begins in the generator room where a turbine jams, causing water to cascade over an elderly pipeworks engineer, Sul (Martin Landau), who attempts a repair while straddling the turbine housing. For closeups, Landau was secured to the set by stunt rigging and endured a torrential soaking while physical effects bombarded him — and his stunt double, in wide shots — with practical spray. "The force of the water coming over Sul's back was something that could never have been done effectively entirely with CG water," said Kit West. "We took great care to get Martin Landau up onto the turbine casing, where he had to appear to be working on the gears. Martin is in his seventies now, but he was a real pro and never complained one bit. We tested the spray many times until we got exactly what pressure we needed, so it wouldn't be too dangerous. When we opened up the pumps, water shot forward from the back of the set in very large fantails."



Doon and Lina make a bid for freedom via a long-forgotten exit from Ember through the generator room, where an elderly mechanic, Sul (Martin Landau), assists their escape. To film scenes of Sul and Doon atop a turbine casing, struggling to free its jammed mechanisms, Kit West's team staged a full-scale physical effect on the forward part of a practical turbine. Pumps passed heated water from a water tank outside the set and targeted spray to soak performers lashed into position. In wider shots, Luma Pictures enhanced the flood with digital set extensions and water simulations.

Sul's heroics un-jam long-dormant mechanisms, allowing Lina, Doon and Poppy to escape the generator room in a boat that surfs a flood of water. The production filmed actors in a boat on a Motion Control Company motion base gimbal, backed by greenscreen, which Luma then integrated with extensive digital water simulations. "We had more than 60 digital water shots," stated Payam Shohadai. "That included many closeup water simulations. Closeup water interactions are frequently done with practical effects, using digital water for wide shots and backgrounds or huge dynamic effects. In this film, all the CG water had to be right up close in camera."

Luma used Next Limit Technologies' RealFlow as the core of its water simulations, creating custom tools to adapt the software to its needs. "We broke water simulations into smaller chunks," explained Vincent Cirelli. "That allowed us to avoid producing high-resolution simulations for every iteration of our shots. Coming from an animation background, Gil was able to understand how those low-resolution simulations were going to sit inside a shot. That made turnarounds for approvals very efficient, and saved us a lot of time." Luma integrated practical effects of water exploding around the turbine with elements of RealFlow water, using depth maps and velocity maps created outside of the software's base package. Compositors then blended digital water cascading over 3D turbine blades and 3D models of generator room interiors.

For extreme dynamic water effects, where a giant tidal wave of water surges through the chamber, Luma subcontracted three water simulations to Scanline VFX, which used its powerful proprietary fluid simulation software Flowline. "We blocked out shots with rough geometry," said Luma sequence supervisor H Haden Hammond. "Gil approved the timing and the relationship of the wave to the camera, then we output a digital model of the set and handed collision geometry to Scanline. They ran simulations and produced iterations to render CG water passes, and then Luma finished the shots in-house." The completed shots included a digital model of a tiny wooden boat carrying Doon, Lina and Poppy on top of the wave, composited with bow waves, wake and greenscreen elements of performers in the boat.

To choreograph the greenscreen shoot for the boat's journey through a labyrinth of flooded tunnels, Luma developed animatics, and then Kit West's team mounted a prop boat atop a Motion Control Camera gimbal. Motion control operators programmed moves, adjusted motion with a recordable waldo interface, and filmed action with a camera on a 50-foot Technocrane. "We set up shots to the parameters of the previz," explained Eric Durst, "and then we adapted that as we shot. As we moved the crane, the camera axis moved and the gimbal moved in real time."

Luma digitally manipulated greenscreen elements, generated tunnel environments and simulated digital water interactions. "We spent a great deal of time analyzing footage of real whitewater and ocean foam," said Payam Shohadai. "A lot of that behavior doesn't happen out of the box with commercial water simulation software. We ended up creating those effects by rendering multiple simulations within the body of the water. Foamy water, for example, is really water with a lot of air bubbles in it. To create that in RealFlow, we rendered separate particle simulations of bubbles refracted through the main water mesh, with motion blur to make it look foamy."

To maximize computing power and allow creative flexibility in water simulations, Luma devised rendering shortcuts. "For the very turbulent water rushing down the cave floor," said Vincent Cirelli,

“we ran only two or three simulations using tools that we created to dynamically chop up the water. By placing a bounding box around our virtual camera, limiting renders to the water that extended just around the corner of the cave, it allowed us to clip away gigabytes of data. We produced low-resolution water simulations very quickly, which otherwise would have taken weeks to render at full resolution.”

H Haden Hammond and Luma CG supervisor Pavel Pranevsky lit the narrow tunnels with raking light that picked out highlights, splashes and cave tunnel walls, and simulated interactive lighting on characters in the boat by matchmoving gimbal elements and generating 3D models. “We created digital doubles of the kids,” explained Payam Shohadai. “We animated lighting on those and used that as an additional pass in the composite to make it look like they were traveling through space.” Compositors layered practical splashes with water simulations and, for wide shots of the boat plummeting down a flume, generated handoffs from greenscreen performers to digital doubles crashing through the water channel into an underground lagoon.

Luma generated a 3D environment for an underwater shot of the boat gliding overhead through the lagoon. Three vendors then contributed to a wide shot of the boat in a subterranean cavern, as it approaches a giant zigzagging staircase. “The staircase was a partial set piece and a matte painting by Zen Haven,” said Eric Durst. “It started off as a locked-off matte painting, and then Gil asked us to give the shot more of a move. Luma generated 3D water and used projection onto 3D stalactites and stalagmites. Amalgamated Pixels then redefined the staircase. If we had designed the shot that way in the beginning, it probably would have been all 3D, but it went through some evolutionary iterations.”

Zen Haven created matte paintings for the children’s ascent up the staircase. The characters then emerge from a cave in a hillside where they witness their first sunrise. The production shot portions of the sunrise on location in County Antrim, outside of Belfast. Eric Durst filmed time-lapse footage of the children’s point of view of a sunrise. The production then filmed the performers on a set representing a grassy rise, backed by greenscreen, and simulated sunlight advancing over the actors’ faces. Zen Haven generated matte painting extensions and Amalgamated Pixels composited the shot using a background element of a rock face photographed in the Belfast Zoological Gardens.



Doon, Lina and Lina's baby sister use a tiny wooden dinghy to ride a surge of water out of the generator room into an underground tunnel. Gil Kenan previsualized the sequence in 3D animatics, and developed animation with Luma. Kit West's team affixed a practical dinghy on a gimbal, allowing the boat to rock about as the gimbal dipped and swayed, and supplied interactive wind and spray. Motion control operators created gimbal motion from previz and real-time manual override controls.

A passing moth leads Lina and Doon to a crevasse in the hillside, which provides a view of Ember in the darkness far below. On location, the production shot Saoirse Ronan and Harry Treadaway leaning over an opening with bluescreen material laid into a recess. Gil Kenan shot the scene with a camera on a crane, peering down toward the bluescreen as the children dropped a small rock into the hole. BUF then tracked a digital matte painting of a deeper opening into the crevasse and rotoscoped the rock as it left Lina's and Doon's hands, transitioning to a 3D-animated rock. A 3D camera move then continued the camera's movement into the hole, following the rock through a lengthy descent to an impact with a lamp and then roof, where it bounced and landed, in one continuous shot, at Loris Harrow's foot on an Ember street. BUF modeled the city in radial sections and focused detail on the impact zone. "We used the same CG model as in the opening shot," explained Olivier Cauwet. "We modeled one neighborhood in high detail, but all around it was medium-level resolution. The stone was CG until it rolled into its final position on the ground."

The film ended on a somber yet hopeful note, concluding a well-crafted and effective depiction of a speculative and thoughtful novel. "The story had very adult themes," observed Eric Durst. "There were a lot of parallels to our environment and the current state of our planet. Martin Laing did a brilliant job of designing the city, creating futuristic technology without being too high-tech. And Gil brought to that an animator's sense of timing. He understood how to blend between previsualized sequences and what could be achieved practically on set. It was a pleasure to work with a director who had that understanding."

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For shots of the three children launching themselves into the underground river, the production originally planned to use real water. Logistics of the shooting schedule caused a change of plans, however, and Luma wound up compositing greenscreen elements of characters in the dinghy into digital water simulations. To create digital water shots capable of withstanding scrutiny, Luma artists researched natural water phenomena and rendered water simulations in layers, blending practical spray with synthetic water using custom depth maps and velocity maps.

Quantum Leap

ARTICLE BY JOE FORDHAM

Ian Fleming's secret agent 007 *James Bond* returned  image for his 22nd film outing in *Quantum of Solace*, thrusting audiences straight into the action where *Casino Royale* left off, with Bond on the warpath after the tragic loss of his former lover at the hands of an international crime consortium.

Directed by Marc Forster — a filmmaker better known for serious dramas such as *Monster's Ball* and *The Kite Runner* — the new film took only the title from a Fleming short story and wove together a plot that had Bond (Daniel Craig) pursuing Dominic Greene (Mathieu Amalric), an environmentalist with less-than-altruistic ambitions. Locations spanned northern Italy, London, Haiti and South America, with action sequences on land, sea and air culminating in a showdown between Bond and Greene in the Bolivian desert.

Forster brought with him a number of prior creative collaborators, including visual effects designer Kevin Tod Haug. "We had worked pretty successfully with Marc before," Haug observed. "Our biggest challenge was working with the constraints in place on the show before we arrived. They were planning a November 2008 release date, which gave us only three months' postproduction. There wasn't time to get into visual effects that were too reliant on CGI. So I asked special effects supervisor Chris Corbould what we could do, driven by physical effects, to complete as much work as possible by the time we were done shooting."

The physical effects department welcomed the collaboration. "Kevin would point out where effects could be better served if we did them practically," Corbould stated. "If we couldn't do them practically, he explained the whole process, why an effect should be done a certain way. If I had an idea how to do an effect better practically, we'd pitch it to Marc. It was good teamwork."

For efficiency, the visual effects work was divided up by sequence and awarded to five effects vendors: The Moving Picture Company, Double Negative, Framestore and Machine in London, and MK12 in Kansas City, Missouri, which handled main titles and motion graphics. "With so much work and such a short post schedule," said visual effects producer Leslie McMinn, "dividing it up by sequences was the only way to do it. Second unit was often shooting simultaneous to first unit, many times in different countries. I stayed with first unit the whole time, while Kevin jumped from unit to unit depending on what sequences we were doing. He would join up with Marc on first unit and then go to be with second-unit director Dan Bradley to supervise effects where a lot of the big action sequences were happening."

Production designer Dennis Gassner built studio sets at Pinewood Studios, west of London, while Chris Corbould established a nearby base of operations at Longcross Studios with a 70-person crew that included first-unit floor supervisor Ian Lowe and second-unit floor supervisor Peter Notley. "At one point," said Corbould, "we had two units in Panama, a crew in Chile, three crews in three places in Italy, and we were preparing six stages in Pinewood for our big finale. I had to flip from one set to

another, trying to be where all the big effects were happening, at the same time showing Marc tests in preparation for what we'd be shooting in three months' time."

To plan complex scenes and action sequences, the production engaged two previsualization companies. Painting Practice, based in Richmond, London, set up operations at Pinewood to develop animatics for early scenes in Siena, Italy, while Nvizage brainstormed an aerial dogfight and a sequence set in a crowded opera house. Two preproduction shoots, the first in Siena, and the second in Baja California, transpired before the filmmakers launched into principal photography.

The film opens with a car chase between *James Bond's* Aston Martin DBS and two Alfa Romeo 159s, shot on location in northern Italy. Chris Corbould's team rigged eight Aston Martins for the chase. Stunt coordinator Gary Powell and Dan Bradley covered the action using aerial and ground-based camera setups, including an Adventure Equipment Ultimate camera crane that extended from the roof of a Mercedes-Benz ML-55 AMG camera car to capture dynamic car-to-car exteriors.

For closeups of Bond driving, Double Negative visual effects co-supervisor Alex Wuttke used the Ultimate arm to capture mobile scenic backgrounds and later filmed Daniel Craig in an Aston Martin rig on a bluescreen stage at Pinewood. "We laid two 80-foot pads of steel plate down in the stage," explained Chris Corbould. "We mounted vehicles on casters and used high-pressure hydraulic rams and cables to yank them about with the same force that they would have had if they were driving." Double Negative 2D supervisor Victor Wade oversaw integration of backgrounds into bluescreen shots, stitching together plates, removing rigs and camera mounts, and adding gun muzzle flashes and bullet hits.

The chase enters a marble quarry, where a Carabinieri Land Rover Defender has its windshield shot out, causing it to crash through a house and plunge over a precipice. Chris Corbould's team staged the crash using a stripped-down Land Rover fired from a nitrogen cannon. A steel cable yanked the vehicle to a halt after 100 feet, preventing a landslide in the precarious terrain.

The Aston Martin survives the chase and enters the medieval city of Siena, seen in an establishing shot that Machine enhanced with a digital matte painting. Bond, on foot, hunts an assassin through Siena's underground cisterns. Dennis Gassner's team built a cistern set at Pinewood, which Corbould's team rigged with large water tanks and recycling water pumps. Bond pursues the assassin through crowds gathered to celebrate the Palio horse race, a religious pageant where thousands of spectators watched 17 bareback horse riders race through city streets.



Actor Daniel Craig returned for his second tour of duty as secret agent 007 in *Quantum of Solace*. Eon Productions assigned director Marc Forster to guide the production,

bringing an art-house edge to the stripped-down tone of the preceding *Casino Royale*. Forster brought in many associates from his earlier work, including visual effects designer Kevin Tod Haug. Haug collaborated closely with Forster's long-trusted special effects supervisor Chris Corbould to realize an ambitious quota of action sequences on land, sea and air, marrying visual effects with physical effects and stunts. Corbould's team rigged an Aston Martin and other vehicles on casters and hydraulic rams, simulating natural forces of vehicles swerving and colliding on a bluescreen stage at Pinewood Studios in England. Double Negative then composited interiors with background plates filmed in Italy.

Production covered the actual event using 15 cameras while Kevin Haug and his team shot hundreds of reference photos and captured as much data as possible employing four Arriflex D-21 cameras positioned around Il Campo. Months later, Framestore accompanied Haug on a second shoot in Siena to film Daniel Craig interacting with 1,000 extras for scenes of Bond fighting his way through the crowd.

Framestore filled out the 1,000 extras to create a much larger crowd. "We spent four hours shooting groups of 25 people against greenscreen," related Framestore visual effects supervisor Jon Thum, "placing two HD cameras at different heights to cover the perspectives needed. I rotated the crowd doing different behaviors through six different positions, and ended up with about 100 takes."

Framestore projected crowd elements onto digital cards, replicating them as sprites in The Foundry's Nuke. Compositors then used still photographs and film footage of banners and crowds from the Palio shoot to dress the environment, combining elements from the real event with elements of Daniel Craig and foreground crowd using rotoscoping and compositing techniques.

The chase leads Bond into side streets and over Siena rooftops. Daniel Craig worked with Gary Powell's stunt team to perform many of his own stunts, assisted by safety wires and stunt rigging. Framestore digitally removed rigging from Siena plates and transplanted Craig's face onto a stunt performer in two fleeting shots. To link locations shot in different parts of Siena, the visual effects team gathered photographs of Siena architecture. Framestore environment supervisor Martin Macrae then oversaw set extensions using a library of 3D walls, balconies and other structures, and combined digital elements with scenic panoramas and rooftop sets built at Pinewood.

Bond finally corners the assassin on the bell tower of a chapel undergoing renovation into an art gallery, a fictional building shot at Pinewood. The action follows the characters as they fall from the bell tower, through the art gallery roof to scaffolding hanging below. "The art gallery fight was one



Bond pursues an assassin over the rooftops of Siena, in Tuscany. Daniel Craig – in safety wires and stunt rigging – filmed many of his own stunts for the sequence, working closely with stunt coordinator Gary Powell. Rehearsals began at Pinewood on soundstage sets approximating the layout of the location. Production designer Dennis Gassner then built two four-sided façades of buildings in a Siena parking lot, which the production used for shots of characters leaping across a street. Framestore removed rigging from Siena plates and used digital set extensions to link locations shot in different parts of the city.

of the few places where we tried some ambitious virtual camera moves,” said Kevin Haug. “We shot a fairly extensive motion capture session with stunt performers and used that as previz elements in a CG chapel. The construction team had already started building the set in the 007 Stage; but, from our previz, we could see it was going to be about 20 feet short, so we halted construction of the exterior, had them finish the inside, and planned the rest as 3D extensions.”

Forster used Painting Practice previsualization to choreograph a vertiginous shot that follows Bond and his opponent in a fall from the bell tower, through a glass-ceiling dome, onto scaffolding below. Framestore pieced together the fall from multiple live-action segments. “They wanted it to feel like there was a cameraman with a wire on his back following the characters down,” noted Jon Thum. “They shot Daniel Craig falling a short distance out of a bluescreen set. They then shot two stuntmen falling on wires, and another element of stuntmen smashing through glass and landing on the scaffold.” The shot was complicated partway through production when the actor playing the assassin was recast. “We took the legs from one pass, put them onto another, and replaced the assassin’s head. The trickiest part was tracking Daniel Craig’s head to the stunt performer’s body as he fell out of the tower.” For the art gallery exterior, Framestore stitched together still photographs to create a 360-degree background of Siena, and modeled the roof and art gallery interior. “We even replaced the set that they fell out of because the speed wasn’t right. The only things we retained were the scaffolding they fell onto and the original Daniel Craig elements.”



Bond and the assassin fall from a bell tower, crash through a glass ceiling and land on a scaffold inside a chapel that is being converted into an art gallery. The production originally planned to shoot the scene in Siena’s Duomo Cathedral, but restrictions caused the production to rethink the location as a fictional building, erected at Pinewood. Painting Practice previsualized the sequence. Chris Corbould’s team then built a hydraulic spinning gantry rig above a partial set. Framestore removed stunt rigging and created digital set extensions, adding the damaged ceiling dome and extending the drop below.

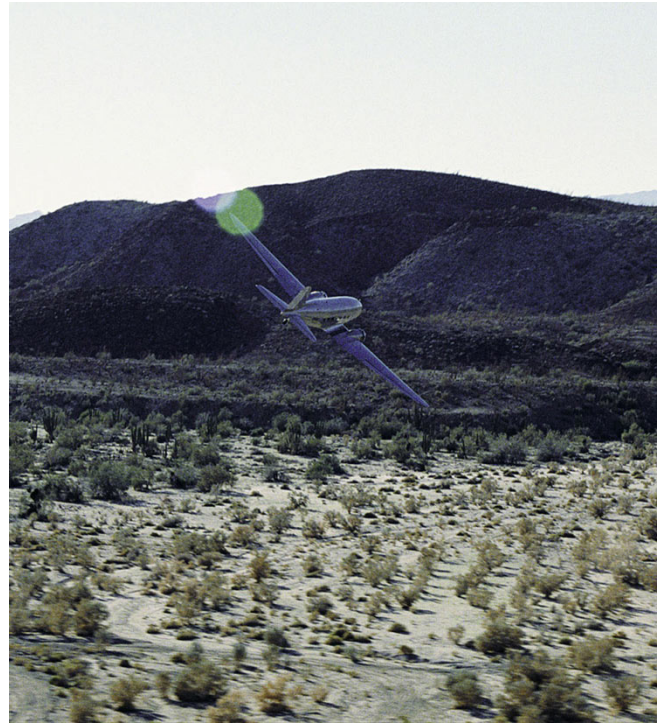
Chris Corbould’s team constructed a hydraulic spinning gantry rig for stunt performers to land on beneath the art gallery dome. As Bond and the assassin struggle for foothold on the gantry, Framestore added the broken dome above and elongated the drop to the art gallery floor. “Every time the camera looked down,” said Thum, “we digitally removed the actors from the set, replaced a CG background, and then composited the actors back in with an immense amount of rotoscoping. We had ropes and limbs flying around, the actor’s hair, pieces of falling glass. We rotoscoped as much as possible and replaced the rest with CG glass and CG ropes using Houdini dynamic simulations.”

Back at MI6 in London, Bond receives a briefing from ‘M’ (Judi Dench), who uses interactive computer readouts to illustrate Bond’s mission. “The script called for a high-tech conference room,” Kevin Haug related. “We had a ‘smart table’ that characters could lay objects on, and it would scan them. Users could touch the display, slide objects around, use icons to grow and shrink images like a giant iPhone, and then slide them up onto the ‘smart wall’ to see them on a larger screen.”

MK12 created graphic user interfaces loosely based on current technology. “Microsoft has a touch-screen table that does something very similar to the one in the movie,” observed MK12 designer Ben Radatz. “There has been research at MIT for smart table and smart wall technology. We looked at all those practical examples and then tried to take them in a different direction. We wanted to create a larger context for every device MI6 was using in the film. We imagined they had a supercomputer that could speak to all the different devices inside MI6 and out in the field, which unified all the graphics.”

Representing the smart table on the set was a large illuminated light box. MK12 printed out a translucent overlay of the tabletop with tracking markers and provided acetate cutouts as practical elements for actors to move across the table. MK12 artists then digitally removed the markers, generated animation on Mac platforms in Maya 3D and After Effects, and tracked graphics to illuminated surfaces. MK12 also furnished custom instrumentation for Bond’s Sony Ericsson C920 cell phone — a product-placement tie-in, given super-spy functionality with thermal and infrared imaging capabilities — and created onscreen graphic composites.

Bond travels to Haiti and rescues a young woman, Camille (Olga Kurylenko), from Dominic Greene’s clutches in a speedboat chase, filmed in Colón, Panama. The chase begins when Bond uses a motorbike to vault from a jetty onto two cargo ships. A stunt performer rode a motorbike up a ramp and drove across two specially prepared barges. Machine digitally enhanced the stunt. “Both of the boats that the stunt performer landed on looked as flat as an aircraft carrier,” remarked Machine co-supervisor Steve Street. “Our job was to disguise the ramp and make it look like Bond was landing on a cargo vessel full of wooden boxes. We shot a lot of practical cargo elements as reference, modeled the cargo and debris in 3D, and hand-animated objects as the bike drove through.”



To investigate suspicious activities in Bolivia, Bond and his companion Camille (Olga Kurylenko) commandeer a Douglas DC-3 cargo plane and engage in a dogfight with a more nimble attacking aircraft. Second unit director Dan Bradley planned the sequence using storyboards and maps of the terrain, and Nvizage generated 3D previsualizations. The production then filmed exteriors in Baja California, with cameras shooting from the desert floor, hilltop locations and air-to-air.

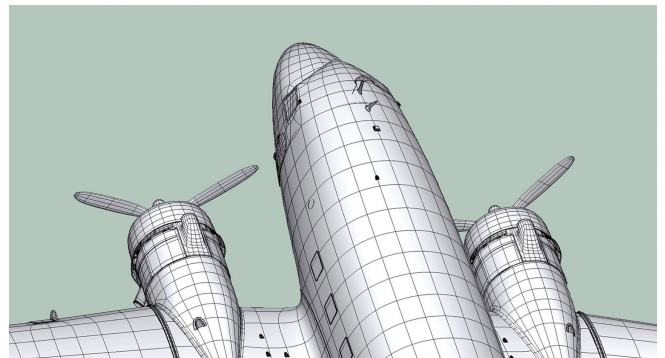


Kevin Haug's team shot greenscreen elements of Daniel Craig on location to use as stunt performer face replacements, aligning angles to approximate camera setups. Machine 2D supervisor Keith Devlin composited elements in Apple Shake and occasionally sampled elements of Craig's face from alternate takes of production footage. "We varied the technique from shot to shot," said Machine co-supervisor John Lockwood. "We sometimes tracked and warped elements that Kevin had shot, and tracked those onto the stunt guy. In other cases, if the hair or head position didn't match, we completely removed the stunt guy's head and replaced it with Daniel's."

To enhance the sense of peril, Double Negative composited aircraft into narrow canyon backgrounds photographed in Imax format and enhanced with scenic textures projected onto 3D geometry.



Strafed by gunfire, the DC-3 emits smoke, which Bond uses to his tactical advantage to hide from and trap his attacker.



Double Negative created digital replicas of aircraft in the sequence using surveys of the practical planes shot on location in Baja. Double Negative used high dynamic range images and ray tracing to create effects of sunlight reflecting on metallic surfaces, riddled the digital DC-3 with bullet holes and used fluid simulations and volumetric rendering to generate plumes of streaming smoke.

Riddle Marine supplied jet boats for the chase, which special effects rigged for the shoot. “The jet boats had aluminum hulls and they could take a heck of a wallop,” stated Chris Corbould. “The stunt boys were driving boats over boats — at one point, Bond drove his jet boat straight over an inflatable rubber boat. He grabbed the anchor off the rubber boat, chucked it in the water, and the rubber boat jerked back.” Corbould’s team rigged the stunt using a nitrogen cannon attached to a cable that fed through a pulley on the seabed. “We placed the rubber boat on the back of the jet boat, and attached the cable to the rubber boat. When they drove over a predetermined point we fired the cannon, which jerked the front end of the rubber boat down into the water and caused it to go end over end with two stunt people on board.”

Machine performed digital rig removal and created a handoff between a stunt performer and Olga Kurylenko for a boat collision. “Bond’s boat and one of the villain’s boats drive towards each other,” explained John Lockwood. “As the boats pass each other, Camille picks up a boat hook and uses it to whack the villain. It was too dangerous to film with Olga in the boat, so they filmed it with a stunt girl, but her face at one point filled the screen. So Kevin filmed Olga doing the action on dry land, against greenscreen, and then we tracked her into the boat.”

Bond later attends a lakeside opera, shot in Austria with 1,000 extras. Machine enhanced the sequence to fill 40,000 seats. To allow flexibility in composites, Machine covered the seats in greenscreen material, shot groups of 50 spectators from a variety of angles, and then replicated elements as Maya sprites to populate the amphitheater.

From Haiti, the action moves to Bolivia where Bond and Camille commandeer a Douglas DC-3 cargo plane to search for the secret behind Greene’s recent desert acquisitions. Marc Forster filmed Bolivian establishing shots in Panama City, using Machine’s digital matte paintings to replace background jungle with distant desert mountains.

For scenes of Bond and Camille inside the DC-3 in an aerial duel with an attacking aircraft, Chris Corbould’s team constructed a full-scale aircraft rig on a mechanical gimbal. “I got hold of a DC-3 from a museum, and we were going to mount that on a gimbal,” recalled Corbould. “When the museum realized the amount of holes we wanted to blow into it, with bullets going through and



Bond evades his attackers by steering the DC-3 straight up, causing it to stall and fall backwards. To film DC-3 interiors, with Bond and Camille tumbling about the aircraft, Chris Corbould’s team built a fullscale mockup of the DC-3 and mounted it inside steel hoops atop a hydraulic motion base. The production fitted the mockup interior with rubber bulkheads to cushion performer impacts as the fuselage swayed, tilted and spun on its central axis, simulating barrel rolls.

chunks being blown out, they weren't too keen on us doing that — the spoilsports! But we used it as a pattern and rebuilt the interior of the DC-3 full-sized. We made it do barrel rolls and other stunts. At one point Bond steers it vertically, straight up, puts it into a stall, and the whole plane falls backwards.”

Corbould engineer Chris Howes drafted a computer design for the gimbal, and then mechanical designer Paul Knowles oversaw the construction of a hydraulic rig capable of supporting the full-sized DC-3 interior. "The bodywork was a series of steel rings," said Corbould. "We had two big steel hoops around that with bearings that allowed us to get the barrel-roll rotation. The interior cladding was aluminum, and the construction department installed rubber bulkheads so the stunt people could fall about and not get too badly hurt." Shot against bluescreen, the behemoth motion base could sway from side to side, tilt up and down, and spin within its bearings. The DC-3 was then replaced with a smaller Savoia-Marchetti single-engine light aircraft for chase plane interiors.

On location in Baja, the visual effects team shot extensive surveys of the DC-3 and Marchetti in order to replicate them digitally; but, from the outset, the



When the DC-3 engine stalls, Bond and Camille jump from the plane and freefall with only one parachute between them.

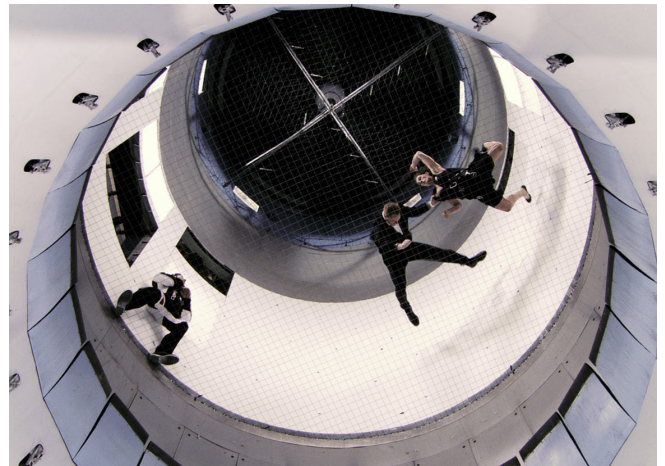


To capture the extreme forces of bodies falling from high

goal was to shoot the dogfight exteriors as practically as possible, with stunt pilot Skip Evans navigating a 95-foot-wingspan DC-3 through narrow desert canyons. The second-unit team covered the action with multiple cameras from ground and aerial points of view, mostly shooting in Super 35. “I shot Imax plates from a helicopter Spacecam mount with a fisheye 30mm lens,” said Haug. “We flew that deep into the canyons to capture background plates seen outside the aircraft interiors. We used an Aerostar light aircraft with Spacecam Systems SnakeHead periscope lenses on the nose and tail to get in very close to the camera planes. We could pan, tilt and track while chasing them at 150 miles an hour. And we did a lot of ground-based photography from mountaintops.”

altitude, Kevin Haug and Double Negative shot performers in a vertical wind tunnel, where powerful airflow held the actors aloft while searing wind rippled their clothes and skin. Double Negative then composited Bond and Camille against sky and desert terrain.

To enhance the claustrophobic feeling of the aircraft weaving through canyons, Double Negative digitally topped canyon walls employing a ‘double-vision’ image reconstruction technique, inspired by research into stereo reconstruction and image-based rendering by AMPAS Sci-Tech award winner Colin Davidson. “We used consecutive frames from the Imax footage as stereo pairs of images,” Alex Wuttke explained. “Each pair of images gave us enough information to reconstruct the canyon in 3D, which we then textured with photographic textures extracted from the plate. We also did traditional digital terrain extensions for other angles, using very large digital cycloramas built from still photography. Our matchmove lead, Joel Prager, then locked everything into place.”



The wind tunnel was located at Bodyflight Bedford, a former aviation test facility outside London. To record the performers in the tunnel, production installed eight Dalsa Origin digital cameras and seven Sony Cinealta digital cameras around the flight area. An airborne cameraman operated a handheld Arriflex 235 film camera to capture actor closeups.

Edited footage of the aerial chase provided reference to guide the gimbal shoot at Pinewood. Double Negative filmed the gimbal in action using two cameras to record an image-based analysis of the motion base, but ultimately matched background plates to aircraft window views based on the natural kinematic response of actors reacting to gimbal motion. The assembled sequence continued to evolve in 'post-viz' rough composites of live and CG elements. "We digitally added damage and smoke," noted Double Negative visual effects co-supervisor Ged Wright, "which they couldn't do in Mexico because it was too dangerous. That turned into something of a story point as Bond uses the smoke to hide from and trap the Marchetti."

Double Negative effects supervisor Michael Waltl used the studio's in-house fluid simulator, dnSquirt, and custom volumetric renderer, DNB, to generate digital smoke plumes, while CG supervisor Dan Kripac oversaw construction of digital aircraft. Kripac's team created the DC-3's metallic finish using high dynamic range imaging and ray-tracing to simulate surfaces reflecting the shifting desert sun.

Bond escapes the dogfight by jumping from the crippled DC-3 with Camille, one parachute between them. Craig and Kurylenko performed the exit from the plane against bluescreen. The remainder of the freefall descent — where Bond wraps himself around Camille and pulls the ripcord in the last seconds before impact — made use of 'event capture' of performers in a freefall simulator.

"Everybody hated the idea of hanging actors from wires," related Kevin Haug. "Instead, Daniel and Olga learned how to skydive in a wind tunnel." Production filmed the freefall sequence at Bodyflight Bedford, a former aviation test facility that contained a 16-foot-diameter, 26-foot-tall cylindrical flight area capped by a 4,000-horsepower fan to keep subjects aloft. Production surrounded the capture area with an array of ultra-high-definition digital cameras that recorded freefall subjects in a three-dimensional data volume. Seeking the highest possible resolution for the camera array, Kevin Haug conferred with visual effects cinematographer David Stump, who recommended the Dalsa Origin digital camera system, which captured uncompressed 4K resolution images using technology that NASA employed on Mars Rover landings.



Visual effects producer Leslie McMin, Dalsa Digital Cinema head of production technology Dan Rosen and Dalsa representative James Petersmeyer confer with visual effects cinematographer David Stump at monitors above eight Codex Digital recorders that captured image data at Bodyflight mission control.

Eight Dalsa cameras were available for the shoot, combined with seven Sony Cinealta digital cameras positioned outside the chamber, and one handheld Arriflex 235 film camera inside the wind tunnel. In addition to the motion picture data, Plowman Craven Associates scanned both actors, providing Double Negative with further data to reconstruct the scene. “We were not just ‘shape-carving’ the actors from imagery,” noted Haug, “and we were not just getting texture maps and projecting them onto 3D bodies. We were capturing the effect of this very powerful wind interacting with the actors’ bodies and their clothes. We shot it at 30 frames per second, with 16 cameras running in sync. At any given moment we could look at the same event from 16 different perspectives and figure out what we needed from that in postproduction. We could change the lens, pull back and do whatever camera moves Marc needed.”



Bond pilots the DC-3 through a desert canyon, luring the more nimble Marchetti to fly beneath him, cresting a saddleback ridge, where it clips a wing and crashes. The production relied on Double Negative to enhance stunt flying, juxtaposing digital aircraft with real aircraft. Double Negative generated the Marchetti crash using two digital planes with dynamic simulations of wreckage and fluid simulations of fire, and created terrain using 3D geometry derived from location footage projected with scenic textures and digital matte paintings.

To synchronize the camera array and provide wireless interlock with the handheld camera in the wind tunnel, David Stump used an Ambient Audio Clockit box, a portable video synchronization and world clock generator that used global positioning satellite data to register timecodes with the atomic clock in Boulder, Colorado. Outside the wind tunnel, cables piped data from cameras to eight Codex Digital recorders that captured four terabytes of raw imagery to disc arrays at 3.8 GB per second.

Double Negative producer Jennifer Silver, Victor Wade and Ged Wright joined Kevin Haug to set up the camera array, observing stringent safety precautions. “It was a mad little space,” noted Wright. “There was a 150-mile-an-hour wind with this massive propeller that sucked, not blew, which was scary! The Bodyflight instructors were very careful about making sure nobody had loose objects in their pockets that could come adrift because anything that got loose would fly up into the propeller and, at that speed, everyone would be in danger.” The visceral nature of the shoot was immediately apparent in dailies. “The most amazing thing that came out of this was the performance. The handheld footage in the wind tunnel with Daniel and Olga had an emotional impact that we never would have gotten by hanging them off wires.”

Double Negative sequence lead Brian Kranz developed digital assets of each performer for virtual portions of shots, using cyberscans, texture shoots and digital hair and cloth simulations. “We were fairly limited in our capture area,” observed Alex Wuttke. “That was simply because we needed so many cameras with such tight baseline constraints to make this technique work. Every time we swung our virtual camera outside the capture zone, we switched to digital doubles volume-carved from the event capture, tracked with textures. But it would have been impossible to animate that kind of performance without the Bodyflight elements to ground it in reality.”

To create sky backgrounds behind falling characters, Double Negative environments supervisor Guy Williams generated 360-degree digital cycloramas from location plates and added interactive atmospheric details. “On top of all the wind tunnel footage,” said Victor Wade, “we layered in digital relighting information, hair and cloth simulations, and environments. In some shots, we added the DC-3 tumbling behind the characters, with vapor flying off them as they fell through smoke emitted from the DC-3.”

To simulate parachute deployment, Chris Corbould’s team staged an element shoot at Pinewood, releasing a parachute in a horizontal stream of air. Production filmed stunt doubles against bluescreen to simulate Bond and Camille being snapped back by the parachute just before impact in a desert

sinkhole. Double Negative generated the sinkhole using scenic elements filmed at a disused slate quarry in the English Lake District. After Bond and Camille recover from their landing, they find an underground reservoir that Greene has created by damming an aquifer. Double Negative generated the shots by combining foreground elements of Craig and Kurylenko, captured on a set piece at Pinewood, with digital matte painting elements of the Llanberis reservoir in north Wales.

The last act of the film plays out at a scientific colony atop a desert mountain. Production shot exteriors of the facility at the European Southern Observatory atop Cerro Paranal in north Chile. The remote location housed Bond’s final confrontation with Dominic Greene and a climactic explosion as subterranean hydrogen biofuel cells detonate and rip apart the building. “They wanted to shoot as much as they could at the ESO center,” recalled Chris Corbould, “but that was going to be tricky. The residents didn’t like anybody smoking there, and it was a problem when anybody created dust driving up the road to visit. This is one of the few places in the world where astronomers can study the sky through telescopes without any air pollution; and so the question came up, could we do explosions, or could we emit black smoke from the windows? The answer was yes — it’s not a big problem to set off a lot of smoke canisters — but I knew it would upset the locals. We had to respect the ecology of the location.”



In a final confrontation with evil industrialist Dominic Greene (Mathieu Amalric), Bond attempts to rescue Camille from a scientific research colony in the Bolivian desert amidst exploding hydrogen fuel cells. The production shot establishing views at the European Southern Observatory in Chile and interiors on six sets built at Pinewood. After several months of testing, Chris Corbould’s team simulated interior shots of the building’s destruction using pyrotechnic and mechanical effects, including large sheets of toughened glass rigged to shatter on cue. The Moving Picture Company added pyrotechnic elements, enhancing the inferno with digital composites.



To maintain the environmental integrity of the European Southern Observatory and surroundings – whose clear

skies make it an ideal location for radio astronomy and the study of seismic activity – production determined that the production built a full-scale, 100-foot-wide exterior section of the ESO building on the backlot at Pinewood. Chris Corbould rigged the set with pyrotechnic effects, employing practical pyrotechnic effects at the location would not be advisable. After reviewing the possibility of using specially formulated compounds to emulate the combustion of hydrogen fuel cells, MPC then integrated using miniature effects to simulate exteriors of the building's destruction. Kevin Haug and Chris Corbould practical explosions with digital reconstructions of the ESO facade, built from photographic surveys of the Pinewood, and use digital composites to integrate the effects into production plates. The center's geometric structure allowed modelers to build panels and repeat them across areas where explosions were required. Compositors then layered dynamic simulations of shattering debris with practical elements, dust, smoke and additional pyrotechnics.

To simulate the destruction of the ESO center, Corbould and Kevin Haug discussed shooting miniature elements; but both decided that a full-scale approach, combined with digital composites, would yield a more immediate effect. Haug's team shot photo surveys of the ESO center, and then Dennis Gassner built six interior sets, as well as a 40-foot-tall, 100-foot-wide exterior section on the studio back lot. The largest of the interior sets filled Pinewood's mammoth 59,000-square-foot 007 stage from floor to ceiling with three levels of walkways and staircases. The physical effects team rigged the set with extensive pyrotechnics and mechanical effects, extensively tested off-site at Chris Corbould's workshop. "It was a very intense fire sequence," observed Corbould. "We had Bond rushing through the burning building as everything was collapsing, rescuing Olga from a burning hotel suite. I wanted to make absolutely sure we could safely drop all the ceilings and do all the fire. Once we worked all that out, Daniel and Olga came to our studio and we rehearsed with them until they became confident with the fire elements."

To evaluate where digital effects could enhance the live pyrotechnic display, MPC accompanied the shoot at Pinewood. "They were able to film more practical explosions with the principals than I expected," remarked MPC visual effects supervisor Angela Barson. "They had fireballs about 20 feet high that appeared very close to the actors by the way they angled them to camera. It was very safe, but the camera setups made it look as dangerous as possible." Filmmakers reviewed playback of pyrotechnic takes on set to judge if additional takes were necessary, or if shots would be better served with digital augmentation in postproduction.

MPC conducted Totalstation surveys of sets to assist digital reconstruction, but all production plates contained practical fire elements, and most digital additions involved 2D composites of practical elements. "We didn't have time to get into lengthy CG fire and smoke simulations," said Barson. "When we were shooting the main shots, if there were cameras not being used, we asked the director of photography to set up additional angles to capture elements. We over-cranked between 32- to 96-frames-per-second, and underexposed so backgrounds went black and gave us all the detail of the fire, and built up a library of fire elements. We then did a separate elements shoot with Chris Corbould's team."

Corbould pyrotechnicians used mixtures of alcohol, methanol and gasoline to create the signature look of biofuel detonations. MPC also shot smaller elements in-house to enhance Bond's rescue of Camille from the burning hotel room. "The hotel room scene was shot with real fire," explained

Barson. “Kevin asked us to make it look more threatening without detracting from the performance. We did a test for adding flames and scorching on the walls. Our 2D supervisor, Mark Curtis, got a heat gun, painted a wooden board, shot elements of blistering paint in high-def, and then matted those into the leading edge of flames on the walls to make it look like the fire was blistering the paint and plaster.” MPC rotoscoped Bond and Camille, creating CG geometry from which they emitted CG steam from the characters’ clothes, then added smoke, sparks and heat distortions.

For shots of Bond and Camille escaping as the scientific colony explodes, production shot clean plates of the ESO center in Chile. Chris Corbould’s team then rigged full-scale fire and smoke effects on the Pinewood backlot set. MPC combined elements through a series of progressive detonations using a base layer of practical elements with digital enhancements. “The building had a very repetitive geometric structure,” explained Barson. “We built a couple of panels and used those wherever the explosion was happening. Our effects technical director, Niall Flinn, created simulations, breaking out fragments; then we added practical explosions and simulated debris flying out. Compositors Steve Sanchez and Stuart Bullen patched those into the building and put the explosion behind that with shattering glass, real and simulated, and masses of fire and practical smoke. In some of the explosions, we added a shockwave by building 3D geometry of the terrain and ESO center and animating particle simulations, so the impact appeared to kick up dust along the ground.”

The latest installment in the 46-year-old Bond movie franchise contained more than 850 visual effects shots, produced in only three months. “There was definitely a sense of having to prove ourselves worthy,” remarked Kevin Haug. “Many of the department heads were American, which was a first on a Bond movie. And it was strange for me to be working with a small group of companies all within walking distance of one another. But I have never worked with better people, and I don’t think I could have done better.”

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Global Warning

ARTICLE BY BILL BUTLER

Known more for its cult-favorite line, “Klaatu Barada Nikto,” than for dazzling effects, the original *The Day the Earth Stood Still* remains the quintessential 1950s monster-movie-with-a-message. Based on Harry Bates’ 1948 short story, “Farewell to the Master,” the Robert Wise film followed a benevolent alien, Klaatu (Michael Rennie), who journeys to earth aboard a flying saucer, accompanied by his giant robot companion Gort. The film carried with it a message of peace and anti-nuclear-proliferation that propelled *The Day the Earth Stood Still* from a mere science fiction flick ‘significant film,’ winner of a Golden Globe for ‘best film promoting international understanding.’

Director Scott Derrickson, a fan of the film, was determined to see the property respectfully adapted for a 21st-century audience, with a retooled storyline that exchanged the original’s anti-nuke theme for an environmental one. Derrickson also wanted to give the film a facelift through the use of visual effects techniques unimaginable to filmmakers more than a half century ago. Derrickson charged veteran visual effects supervisor Jeffrey A. Okun and effects artists at Weta Digital, Flash Film Works, CosFX, Cinesite, Hydraulx and Digital Dimension with updating the relatively simple visual effects of the 1951 film into an impressive array of computer generated imagery, without abandoning the original’s story intent.

“Staying very true to the original film and yet updating it was an interesting dilemma,” said Jeff Okun. “Scott did that by asking, ‘If they’d had the tools and the budget in 1951, what would they have done?’”

With this question in mind, Derrickson and his team redesigned the central visual elements of the film, from the alien spacecraft to Gort, and planned key effects and action sequences through previz executed by artists at POV and Image Engine. To update the single flying saucer that lands in Washington, D.C.’s Capitol Mall in the 1951 version, Derrickson and his concept artists envisioned a sphere measuring 300 feet in diameter, which hovers

image



For his remake of the 1951 science fiction classic, *The Day the Earth Stood Still*, director Scott Derrickson strove to pay homage to the original while also updating its message and science. Derrickson and visual effects supervisor Jeff Okun also upgraded the original’s low-tech visual effects, throwing 21st-century technological power and know-how at effects elements such as Gort – robot companion to the alien Klaatu (Keanu Reeves) – and the extraterrestrial visitors’ mode of transportation. In the new film, Klaatu arrives on earth to deliver a warning against environmental recklessness, traveling via an illuminated sphere rather than an archetypal flying saucer.



over Manhattan, and then lands in Central Park, with Klaatu (Keanu Reeves) and Gort emerging from the spherical object. In other sequences, smaller spheres appear all over the planet — some rising from oceans and swamps, others rising out of arctic ice.

Cinesite London contributed to an opening scene, set 100 years earlier, which establishes the arrival of these smaller spheres. “We did the opening 1,200-frame shot of the movie,” said Cinesite visual effects producer Ken Dailey. “The shot travels through the Fox logo, and then cuts to a starfield. There is a slow tilt-down through the stars, to a view of the Karakorum Mountains, in the Himalayas. The first part of the shot was a matte-painted starfield; and then, for the mountains, we did a 2D matte-painted projection onto geometry. Layered over the top of that were all kinds of practical elements — moving clouds and blowing snow — to give it some life.”

Back in the present, the sphere bearing Klaatu lands in Central Park. Though the film would be shot almost entirely in and around Vancouver, Jeff Okun and his team shot a series of helicopter plates over New York for the Central Park scenes — one set at sunrise, one set just after dusk, and another set at night. The team also photographed Central Park at ground level, facing ecological challenges ironically linked with the film’s conservation theme. “The city sold the park to a conservancy that has a lot of rules,” noted Okun, “one of which translated to us not being able to put a tripod on the grass anywhere in Sheep Meadow. We went back and forth with them, saying, ‘What if we get a very lightweight tripod and put the legs of it in three tennis shoes on the ground?’ And they said, ‘No.’ That complicated things tremendously because the plan was to shoot HD footage and stills of everything so we could re-create the location as a 2D matte painting for any angle that we needed.

“What we ended up doing was just walking around with the cameras and shooting as much as we could that way. Then, Michael Sarkis, the Weta digital data wrangler who was with us, found a manhole cover in the middle of the park, and we put our tripod on that. Michael shot high dynamic range images at every hour of the day and night from that position, as well as from cement walkways on the exterior of Sheep Meadow.” For higher angles, the team shot high-definition stills from the rooftops of surrounding buildings and from the 28th floor of the Essex House hotel, using a range of lenses and shooting at different times of day to capture changing light values.

Under the supervision of Kevin Rafferty and Chris White, Weta Digital used the HD images to create a series of CG environments. “Most of the environments you see in Central Park were our reconstructions,” said Chris White. “Using the photographic reference, we built a panoramic cyc for that entire area.”

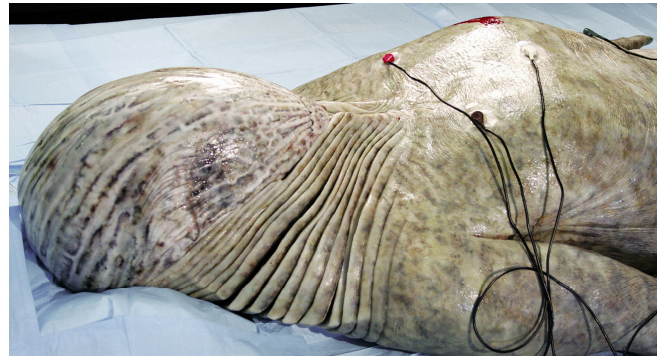
Live-action ground scenes of military and government personnel watching as the sphere hovers over Sheep Meadow and then lands were shot in a variety of parks and soundstages in Vancouver, where director of photography David Tattersall set up interactive lighting rigs to simulate intense illumination emanating from the sphere. “He had a scissor-lift with more lights on it than I’ve ever seen in one place,” said Jeff Okun. “He put the lights behind a white silk to create softer shadows,

One of the most difficult aspects of the 1951 film to adapt was Gort, an iconic character originally portrayed by an actor in an unsophisticated helmet and suit. In redesigning the robot, concept designer Aaron Sims and artists at Weta Digital combined elements of the original Gort with the towering, featureless characteristics of the monolith in Stanley Kubrick’s 2001: A Space Odyssey. Weta Digital’s final CG character stood nearly 30 feet tall and had a faceless mask capable of emitting a powerful light ray.

and programmed them to create undulating patterns of light. These lights were tremendously bright, and gave all the actors wonderful tans.”

Weta Digital incorporated into those plates a glowing CG sphere, confronting challenges inherent in spherical shapes — difficulties Jeff Okun knew well from his work on the 1998 film, *Sphere*. “I learned many things about spheres on that movie,” Okun remarked. “In one of my first meetings on this film, I warned them that a sphere is one of the most difficult things in the world to deal with. It looks flat unless it’s lit properly. It has no dimensional angles — every way you look at it, it looks the same. And it has no scale. In a lot of our shots, nothing was going to be in the frame with the sphere to give it scale, so there would be no way to know how close or far away it was, how big or small it was.”

To overcome these problems, the visual effects team aimed to integrate as much depth and dimensionality into the sphere as possible, designing it as a volume of gas illuminated from within by moving, colored lights. “We didn’t look at the sphere as a spaceship,” recalled Okun, “but more of a traveling portal — as if Klaatu has stayed on his planet and walked through this hole to get to our planet. So, instead of the types of internal structures that you would see in a typical spacecraft, this sphere had to suggest alien technology. But Scott Derrickson also wanted it to have terrestrial elements to lend it some reality. We looked at pictures of earth from space to see what it is that gives an atmospheric structure the feel of three-dimensional curvature, and we found that it required different kinds of cloud and lighting layers. We also studied the planet Jupiter and different liquid simulations. We took all of that visual reference, added in some water tank technology, and came up with 20 or 30 iterations of this sphere.”



In the remake, Klaatu evolves from a bioluminescent entity within a gelatinous casing to a ‘newborn’ version of Keanu Reeves, and finally to the fully human-looking character. The newborn emerges on an operating table, as the gelatinous outer skin – damaged by gunfire – dissolves and melts away. Though the initial bioluminescent form and the newborn Klaatu were both Weta Digital CG creations, shots of the organic cocoon were realized with a practical suit created by Todd Masters and his Masters FX crew. To realize an in-camera dissolving effect, Masters FX sprayed the prosthetics with chemicals from off-camera, or pumped them through tubes mocked up to look like EKG sensors.

Weta Digital artists Mike Perry and Mark Davies incorporated layers of cloud-like structures within the gaseous volume, and infused it with light and scattering effects to create the appropriate sense of depth. “It was all done in the shader,” explained Chris White, “and, since it was a sphere, we could do it mathematically. We didn’t have to have any geometry. It was a series of painted textures, which evolved so that each layer had its own individual motion. All of the detail and structure came from the actual textures, the gaseous render of all those layers and the light bleeding through. The lights were constantly moving around inside of it, shining through different layers of colors and these cloud shapes.”

In Central Park, Klaatu emerges from the giant sphere as a creature of light contained within what is later discovered to be a kind of life-support suit. “We were adamant about having a continuity of

look in all the alien technology,” Jeff Okun said, “so we carried the look of the sphere into designs for Klaatu as he first appears. But Klaatu is an ever progressing, constantly developing creature who adapts to his surroundings; and so, even though he is essentially light, he begins to adopt a new form, finally evolving into the human-looking character played by Keanu.”

Concept designer Aaron Sims rendered drawings of Klaatu in his original bioluminescent form, which Weta Digital used to create its digital Klaatu. Weta tracked the CG character into plates featuring a performer in a green suit and hood interacting with scientist Helen Benson (Jennifer Connelly). “The performer gave Jennifer Connelly someone to act with,” Okun observed, “and Weta used that performance as animation reference for CG Klaatu, which was a human-shaped character.”

“He’s bioluminescent,” added Chris White, “but we had to build some internal structure to actually generate the glow. So there was this outer form, and then several layers illuminated with different colors. The trick was making him visible so that he would be a real presence in the shot, but at the same time not making him too well defined. He had to remain a mysterious presence at first.” As the lighting effect is dialed down, Klaatu appears as a more physical form, which begins to walk and move around. “There was a very specific walk that they wanted for him; and we motion captured a number of different walks to develop one that worked.”

As in the original movie, Klaatu’s alien presence strikes fear into the hearts of the observers standing awestruck at the sphere’s landing site, and an unseen assailant shoots him. After being rushed to a nearby hospital, Klaatu’s bioluminescent structure gives way to a full-size humanoid Klaatu with features of a newborn. “The bullet not only wounds Klaatu,” explained Jeff Okun, “it causes his outer life-support suit to shut down — and as it does, Klaatu becomes more and more recognizable as a humanoid shape and body. The outer form essentially melts away, and it becomes clear that what everyone has mistaken for the alien is actually just a life-support suit for the real alien. The suit acts as an incubator for the newborn Klaatu, which is this creepy, thin CG version of Keanu. It’s just another stage in his development from a light creature to a physical creature.”

The surgery sequence features a transition from practical effects designed and executed by Todd Masters and his Masters FX team to the CG newborn Klaatu created by Weta Digital. Masters FX performer Sam Polin wore a practical suit for shots of the injured Klaatu on a gurney, on his way to surgery. “It wasn’t a very complicated suit,” said Todd Masters, “because this creature, at this stage, has no eyes and no mouth; however, that in itself is a complication because we had to feed oxygen and audio to our guy inside when the head was completely sealed off. It was supposed to look like Klaatu when he first comes out of the spaceship — kind of blubbery and puffy. Bernhard Eichholz and Dan Rebert supervised the build, which was mostly a silicone and foam latex composite. We matched the gelatinous, translucent material you see in the next surgery scene as much as we



Military personnel remotecontrol a Reaper drone attack on Gort in the skies over New York. Cinesite London composited screen graphics and helicopter POV plates into on-set monitors for the shots. Cinesite also created the two Reaper drones digitally, basing the model on real drone aircraft and incorporating them into 22 shots in the attack sequence. In the course of the action, one of the drones launches a missile toward Gort, which the robot destroys with a ray beam. Cinesite generated the 3D missile, and added a smoke trail and heat haze.

could — but you can't make a full suit out of translucent silicone. It would weigh 700 pounds! So we did a composite. The head was also an amalgam of materials, including clear fiberglass for the shell." The suit featured gill-like structures made of silicone that opened and closed via bladders. To better link the suit to the original bioluminescent character, Hydraulx added a digital glow to some of the practical effects shots in postproduction.

As doctors probe Klaatu's body to remove the bullet, the outer suit begins to disintegrate and fall away in pieces. Masters and his crew created gelatinous pieces for insert shots of the self-destructing suit. "We never see the whole body dissolving at once," observed Masters, "but we do see inserts of the dissolving torso and head and other little pieces. We made those pieces mostly of Thermo-gel. They were cast hollow and injected with a specially formulated thick slime we developed for Slither. That gave it a very natural weight when dissolving. The intrinsically colored translucent gel dissolves nicely if you spray certain chemicals on it." Bernhard Eichholz devised plumbing so that the chemical could be pumped into the prosthetic pieces, making it appear as if the suit was dissolving from within. "The character has EKG tabs on him in surgery, so we made a bunch of phony ones that were actually irrigating the chemical liquid through the pieces to make them dissolve and fall away. In some shots we just misted the chemical onto the piece from off-camera."

The surgery sequence then transitions to the CG newborn version of Klaatu. Aaron Sims and artists at *Spectral Motion* rendered drawings of the character, illustrating features such as a baby's translucent, pale skin and soft, fine hair. "We did a lot of referencing of what babies look like when they're first born," said Jeff Okun. "The challenge was to work those baby-like qualities in with the body of a full-size, adult man." Sims' drawings showed the character in the fetal position, underscoring his vulnerability outside the life-support suit. "For one of our references, we used the cover of the John Lennon/Yoko Ono album where John is naked and curled up next to Yoko."

At Weta Digital, Marco DeLucca modeled the frail, emaciated Klaatu body, while Ben Thompson and Mel James worked on shading and texturing. "We used subsurface scattering to get the translucency of the skin," said Chris White, "and we made sure the skin texture had a lot of pore and other detail in it. We spent a lot of time on those nuances."

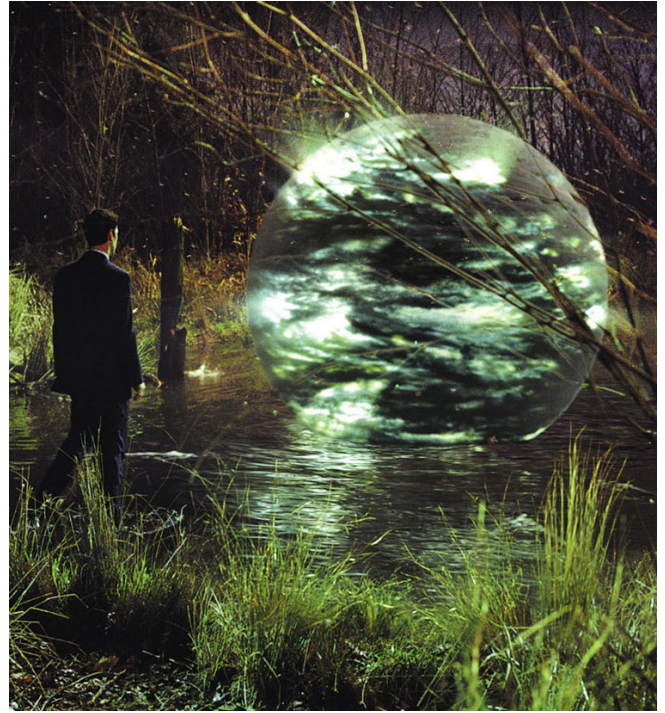


Gort is ultimately captured and held in a giant missile silo for observation. Lighting and integrating the robot into set environments presented a range of challenges, largely due to the character's monolithic, uniform look. Since Gort had no facial features to produce expressions, Weta's animation team had to rely entirely on body attitude and head movement to relay his frame of mind in any given shot. Weta captured Gort's movements in motion capture sessions with performer Shane Rangi, who wore weights on his wrists and ankles to create the massive character's weighted articulations.

Animation of the character rolling over onto his side and into the fetal position was obtained through motion capture of Masters FX performer Sam Polin. “He did a great job for us,” said Jeff Okun, “and we took a lot of emotional and performance cues for the CG creature off of him.”

Newborn Klaatu soon progresses to the stage of adult male human — as played by Reeves — and is seen applying ointment to his stitched-up chest wound. “There’s a closeup of the wound healing with the application of this ointment,” said Digital Dimension CG supervisor Andrew Roberts, who oversaw the shot. “They wanted the healing to look organic and real, almost like you were watching time-lapse photography. So we tracked this CG wound to the character, which then healed in a very natural way. We had to do a lot of research into what you would see in a wound like this — subcutaneous layers, fat layers, other tissue — and all of that was modeled and animated by Hansoo In. Technical director Brian Demetz did a lot of work with reflection and refraction to make it look like there was this Vaseline-type ointment on top of the wound.”

Seeking to determine his threat to mankind, government scientists interrogate Klaatu and conduct a polygraph test. Cinesite London contributed images to the interrogation scenes, as Klaatu uses his alien powers to investigate the hospital’s security systems and plan his escape. “We did 12 shots for this polygraph room sequence,” said Ken Dailey. “The camera pushes in on Klaatu’s eye, and then travels into his eye, through his brain, down through the building’s cables and electrical circuits and into the security cameras. Then the view is from the security cameras, looking around to see where the guards are. The camera then whips back around, into the security camera again, and pulls back out through Klaatu’s eye. This process repeats a number of times throughout the sequence, each time exploring different hallways and corridors.”



In a remote grove, Klaatu summons a sphere – a smaller version of the luminescent vessel in which he arrived – from the depths of a swamp. Weta Digital generated spheres as volumes of gas illuminated from within by swirling colored lights, suggesting advanced alien technology. Weta artists devised layers of painted textures, each individually animated to churn through the sphere.



An illuminated prop that stood in for the sphere on the set provided a physical object with which Keanu Reeves could interact in the scene, and also cast interactive light on the actor.

The look of this journey through Klaatu's organs and the building's circuitry and cameras took some time to develop. "It was quite abstract, and so it went through a number of iterations before Jeff Okun and Scott Derrickson settled on what they wanted," said Dailey. "But once we settled on the look, creating the images went quite smoothly. We started off with a live-action greenscreen element of Keanu, a special camera pushing in on his eye as closely as possible. We transitioned from that to the full CG interior of his eye, and then linked to our cables, the insides of power conduits and plugs. There was a little bit of animation through there, and then you're inside the security camera, which was a 3D build. The view of the guards and hallways was a live-action plate, and we did some stabilizing and 2D work to blend from that back onto the security camera in the whip-pans to make it feel like one consistent move. We also added reflections of the corridor and guard in the camera lens."

Klaatu escapes the hospital and reunites with Gort. The towering robot — played by Lock Martin in a simple helmet and suit in the original film — is one of cinema's most iconic images; and so Scott Derrickson and the effects crew understood that homage had to be paid to him. Yet, the filmmakers also knew that a similarly unsophisticated suit-and-helmet approach would never fly with modern audiences. "Gort was probably the most difficult thing on the entire show," admitted Jeff Okun. "There's a huge fan base for Gort and we felt a great responsibility not to disappoint them; but we had to update it and make sure it looked good on screen. We had to come up with something that was cool in look and action and that would deliver, story-wise."

Initially, the filmmakers conceptualized Gort as a four-legged alien that was part metallic, part organic material. "All of his edges were like razor blades," said Okun, "and he had tentacles at different points on his body." Coming onto the show seven months into Gort's development, Okun felt strongly that the design had strayed too far from the original character. "We were up in Vancouver about six weeks before shooting, reviewing the Gort design. I took the position that Gort needed be a humanoid thing. Erwin Stoff, the film's producer, agreed. When we said that, it was as if everyone had been thinking the same thing, and they just needed somebody to say it first. So we threw out that Gort and began redesigning him from scratch. Aaron Sims and Weta came up with a very good version of Gort that paid homage to the original, and everyone was happy."

In the redesign process, the visual effects team found inspiration not only in the original robot, but also in the iconic monolith from Stanley Kubrick's 2001: A Space Odyssey. "One of the reasons that the monolith in 2001 has so much impact is because it's a completely blank slate," Okun noted. "You can project onto it everything that you fear. We decided to do the same thing with Gort, making him a sort of monolithic figure, without a real face. We gave him some body posture to make him look



Klaatu's interaction with the swamp sphere causes others to appear all over the globe. Weta Digital created an all-CG shot of a sphere rising from an ocean, complete with CG water, skies and boat. Weta used the shot — one of the first the team tackled — to work out all of the specific properties of the sphere and determine how to generate the look digitally. Weta artists produced several iterations of the shot before finally coming up with one that created an appropriate sense of spherical mass.

more threatening; but, otherwise, he is a nearly 30-foot-tall monolith.” Though powerful, the monolithic design presented a range of challenges when it came time to incorporate Gort into shots. “We discovered many problems with the design — problems having to do with the color of it, the shape of it, how it moved. He was too black, for one thing, and ended up looking like a silhouette. And he was so monolithic, he didn’t have any dimension to him. In shots of him in front of the sphere, he looked like a stick figure because the light was masking his features. Making Gort look good in the shots became this huge puzzle to solve.”

Gort’s animation was a critical piece of that puzzle. Derrickson, Okun and Weta animation supervisor Eric Reynolds opted to capture Gort’s movements in a motion capture session with Shane Rangi, a tall Maori actor who had worked in a number of Peter Jackson’s films. “He’s an amazing guy,” said Okun, “and we got this performance out of him that was all body attitude. We got a sense of performance just by the tilt of his head and the weight of his walk. We put weights on his wrists and ankles, and suddenly we were 90 percent of the way to where we needed to be.”

Late in the movie, Gort is revealed to be not a single robotic unit, but rather a structure made up of hundreds of thousands of individual nano-bots — dubbed ‘aphids’ by the effects team — which ultimately break away to form swarming clouds that consume everything in their paths. “The nano-bots’ only purpose is to consume things,” observed Okun. “They’re like little factories that consume a substance, then use mitosis to split into two nano-bots. The more they consume, the more of them there are.”

Weta artists designed the aphid, rendering hundreds of versions before arriving at a nano-bot with legs and razor-sharp teeth. “We went through a gazillion iterations of this bug,” Okun recalled, “starting with the pure mechanical thing and going fully organic with it. Finally, we did a combo version that was organic and mechanical.” A contributing influence on the aphid design was how they would look when grouped together in the millions to form Gort. “An individual nano-bot is the size of the head of a pin; and when we had millions of those making up a character that was 28 feet tall, it created a very uniform surface, which was kind of boring. To break up Gort’s surface, we decided that the nano-bots could be a variety of sizes, everything from the size of the head of a pin to as big as a brass brad that holds a script together. That break in uniformity helped with all of our puzzle issues — how the army of nano-bots moved, how they reflected light — and it gave us the ability to disrupt Gort’s surface, yet maintain a shape.”

To create the movement and behavior of the aphid swarm, the visual effects team looked to nature reference, such as underwater footage of minnows and footage of starling flocks flying and



Later in the film, alien spheres depart earth from various iconic locations. For a shot of a sphere rising from the pyramids at Giza, CosFX started with a still photograph of the site, and then separated the elements and positioned them in 3D space to add depth to the shot and accommodate a crane-up camera move. CosFX also painted in a more dramatic sky and added two spheres.

changing directions in perfect concert, as if of one mind. “A flock of starlings looks like a giant geometric shape that is contracting and expanding and twisting at the same time,” Okun explained. “Basically, they keep the same amount of space between themselves and their neighbor at all times; and if their neighbor turns, they turn, so there are no collisions. The real trick is, ‘Who’s leading the group?’ The answer is, whichever starling is pointed forward on the leading edge, that starling is the leader. He is free to go wherever he wants, and the whole crowd will go with him. And when they change directions, whoever is pointed forward on that new leading edge is the new leader. We applied that flocking behavior to our particle systems to get these masses of nano-bots to move that same way.”

The starling-inspired swarm animation required new tools, developed by Weta ‘swarm team’ members Allen Hemberger and Ronnie Menaham. “They worked on tools that would give us these specific flocking characteristics,” stated Chris White. “We wanted our particles to stay a certain distance from one another, just as flocking creatures do. With a lot of particle simulations, things are just influencing the particles. For this, it was important that the particles influence one another and move with some intelligence.”

Grand-scale aphid attacks occur when Gort escapes a disused missile silo — the setting an obvious nod to the message of the original film — where he is under observation. In the scene, Gort disintegrates into the aphid swarm, which subsequently attacks and consumes everything in the environment, eating through metallic structures. The sequence included shots of the swarm eating through a technician’s haz-mat suit. “In the live-action plates, the technician is moving around and trying to swat these things off,” remarked White, “and we had to see his clothing dissolve away. They had done some corrosion on his suit in different stages on set, but we had to show the transition from no corrosion to dissolving away. Most of it was done with tracking and 2D work by our paint department. We also built all the metallic structures and objects you see being corroded in CG.”

Late in postproduction, the filmmakers extended the silo sequence to include a scene in which the aphid swarm bursts through the silo doors and engages with the military. Overtaxed with its original slate of shots, Weta was unable to take on the new scene; and so Jeff Okun commissioned Hydraulx to produce a dozen combat shots in only seven weeks, augmenting live-action footage shot in the California desert by Jim Rygiel. “Originally,” noted Hydraulx co-founder and supervisor Colin Strause, “they didn’t have a sequence where you saw the aphids escaping from this chamber. There were only closeups of it inside; and then in the next shots this black swarm was attacking a stadium in New Jersey. They decided they wanted a cool bridge sequence between those two. So they filmed out near Palmdale, using a few rented military vehicles and about 35 extras — and then



Gort escapes the missile silo and disintegrates into millions of nano-bots – dubbed ‘aphids’ by the visual effects team – which form a destructive cloud that consumes everything in its path. Weta Digital designed the individual nano-bot as a partorganic, part-mechanical entity with legs and razor-sharp teeth. For a shot of the aphid swarm consuming an 18-wheeler traveling down the New Jersey Turnpike, Weta used location reference to build a completely CG environment, with roadside trash and polluting smoke billowing out of industrial sites to emphasize mankind’s environmental disregard.

we had to add everything else. We built a completely CG base exterior. We turned their dozen vehicles into about 150 vehicles. We built super-high-resolution 3D assets for a Howitzer tank, an Abrams tank, a Bradley troop transport, a Humvee. We had 3D closeup shots of vehicles firing. Joe Harkins, who is our chief character TD, built this entire system for doing simulations on the treads of the tanks; so when the tanks fired, the treads would actually jiggle and roll correctly under the wheels.”

Hydraulx also used Massive to create hundreds of soldiers firing their weapons. “We had 3D stunt doubles on top of Humvees,” said Strause, “actually firing machine guns. There were rocket launchers firing. There was so much tracer fire, it looked like a scene from *Star Wars*.” Hydraulx also created the aphid swarm for the scene — the only swarm shots in the film not provided by Weta. “We did a particle simulation swarm. Weta sent over a couple of their finals, and we just looked at them and reverse-engineered how they did it.”

The escaped aphid swarm targets a truck driving down a New Jersey turnpike. Weta used location reference to construct a completely CG environment for the scene. “There was a very specific look that they wanted of this truck going down a Jersey highway,” said Chris White, “a look that was important to the environmental theme. They wanted ugly factories along the highway, trash on the side of the road — things representing the destruction that man has done to his environment. That was done with a combination of matte painting and some compositing work. We did a fair amount of placing things within Nuke to build up an environment; and we did a lot of 3D work, as well.”

To stop the destruction, the U.S. military sends two Reaper drone aircraft. Cinesite London created 22 drone shots, sharing assets with Weta, which realized shots that included aphids and the Central Park sphere. “We did shots of these two military drones flying over New York,” explained Cinesite CG supervisor Stephane Paris. “We based our drone model on a real Reaper; but, instead of a propeller, which is on the Reaper, we updated ours with a jet engine. All the textures came from drone photographs on the Internet and from production.”

Cinesite composited CG drones into helicopter plates shot in the skies over New York, and also modeled a 3D missile for a shot of a drone launching the weapon. “We created the missile with a smoke trail and heat haze,” said Paris. “Gort destroys the missile with a ray beam, then takes control of the two drones with a second ray beam, and crashes them into an army tank, which explodes. We did the exploding tank in CG.”

In a warning as to the consequences if mankind does not clean up its environmental act, Klaatu directs Gort to ‘still’ the earth — illustrated in CG shots of a global-wide electronic and technological



The aphid swarm destroys a stadium in New Jersey. Weta Digital generated the aphid swarm via particle simulations, basing its movement on nature reference footage of starlings and other flocking creatures. Weta's dedicated 'swarm team' developed new tools to create specific flocking behaviors, dictating that particles maintain set spatial distances to avoid collisions and move in precise concert. To avoid a swarm look that was too uniform, Jeff Okun and Weta artists determined that individual nano-bots would be a variety of sizes, from the size of the head of a pin to the size of a brass brad.

power-down, realized by Flash Film Works, CosFX, At the Post and Digital Dimension. Disabled sites include a satellite array in the New Mexico desert, a field of oil pumps, and the Golden Gate Bridge. The Golden Gate Bridge sequence begins with an aerial view, the camera flying over the bridge, looking down on traffic as the lights on the bridge go out and the cars lose power. “These were our most challenging shots,” observed Andrew Roberts at Digital Dimension, “because the Golden Gate Bridge is something everyone is familiar with. CG artist Matthew Lee modeled the bridge, and we textured it, matching the clean, matte finish of the real bridge. Then we added layers of weathering, bird poop, dirt, soot, and variations of specularity, which made it look much more real.” Technical director Rudy Cortes set up a particle system to simulate the traffic on the bridge, slowing down and veering left and right.

Another standstill scene takes place in a bullet train station in Tokyo, where the train slides to a stop as its lights flicker off. “The bullet train sequence turned out very nicely,” said Roberts. “Jeremy Jozwik, the technical director who modeled the train, had been to that location, and so he was able to add a lot of detail and realism to these shots. There was the CG train in the foreground, CG rails, CG houses in the midground, and then Mount Fuji in the background — all synthetic except for Mount Fuji.”

Although significantly reworked for a new audience, *The Day the Earth Stood Still* in its updated form remains true to the original’s message that the fate of the planet will be determined by human behavior. The task of the visual effects team was to underscore that message through imagery, while also adding action and spectacle. “The original movie had almost no visual effects,” Jeff Okun said.

“Mainly, it was a movie about this guy walking around, trying to get to know humanity and deliver this message. To that end, Scott has remained true to the original, and kept the effects shots to a minimum. But we still got the opportunity to create a lot of really cool and interesting new visuals, and we’re extremely happy with what we’ve done.”

The Day the Earth Stood Still photographs copyright © 2008 by Twentieth Century Fox. All rights reserved. Production still photography by James Dittiger and Doane Gregory. Special thanks to Helen Arnold, Judy Alley, John Duquesnay, Dan Harary and Chrissy Quesada.



The military launches a full-scale assault on the 300-foot-diameter ‘mothership’ sphere that settles in New York’s Central Park. Black smoke from the attack clears, revealing that the glowing orb has sustained no damage. The visual effects team shot a series of helicopter plates over New York for the Central Park scenes, and also shot highdefinition still photographs of the park on the ground and from the rooftops of surrounding buildings. Weta Digital used the HD images to create CG environments and panoramic cycloramas for Central Park scenes set at sunrise, dusk and night.

The Unusual Birth of Benjamin Button

ARTICLE BY JODY DUNCAN

In 2005, commenting on the feasibility of creating a wholly convincing computer generated human for film, animation and visual effects icon Phil Tippet made the following observation: “...for this kind of character to work, it’s got to work in every single shot. It’s not like a dinosaur that can be creaky in one shot, but it doesn’t matter because you still get the overall gestalt. A human character has to be a character, and if it breaks, it breaks — that puts a huge onus on the creative and technical staffs.”

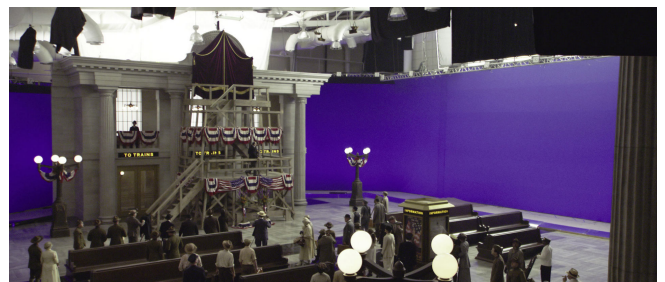
That onus weighed heavily on director David Fincher, producer Ceán Chaffin and Digital Domain visual effects supervisor Eric Barba as they prepared for reactions from a test screening audience to their in-progress *The Curious Case of Benjamin Button*, a film loosely based on a short story by F. Scott Fitzgerald. For the first time, the team was unveiling the character of Benjamin Button (Brad Pitt), who is born with all the debilitating characteristics of an octogenarian and then ages backwards, each year looking younger and gaining more physical strength and mental acuity. For the first hour of the film, in which Benjamin looks to be a man in his eighties, then seventies, then late sixties, Fincher and Digital Domain’s creative and technical teams had realized the character by marrying Brad Pitt’s captured performance to a CG head that was then tracked to a live actor’s body. At this initial test screening, they were going to find out if the audience would buy into Benjamin as a real human being, or if their digital character would — as Tippet had warned — ‘break.’

“Eric and his team from Digital Domain were all there,” Ceán Chaffin recalled, “and before this screening, they were all thinking, ‘Okay, here we go

image



The Curious Case of Benjamin Button encompasses the entire lifespan of Benjamin Button (Brad Pitt), who is born with the physical characteristics of an octogenarian, and then ages backwards, gaining strength and a more youthful appearance with each passing year. Though convincingly aging Brad Pitt for the early years of Benjamin’s life was the production’s overarching effects issue, the film also required visual effects to depict its many period settings, such as a fictional train station that opens the year of Benjamin’s birth in 1918. The train station and its backwardsrunning clock – visual metaphors for Benjamin’s curious aging process – are featured throughout the film.



— we’re going to get it.’ But afterward, when we went through the audience note cards, we were amazed to see that no one asked, ‘How did you do this?’ Not one person brought up the subject of how we did it. They just talked about Benjamin, the character. They just believed him.”

“That had been our goal, from Day One,” observed Eric Barba, “to bring this character to life so that when someone is watching the movie, all they are thinking about is the story and the character. We didn’t want anyone to be taken out of the story by some kind of obvious effects technique.”

The screening audience’s response was vindication for years of effort that Fincher and his team had dedicated to the film. By the time Paramount Pictures and Warner Brothers officially greenlit *The Curious Case of Benjamin Button* in 2006, Fincher had spent more than a decade thinking about the project — and its long and somewhat tortured development had predated even Fincher’s involvement. Producers Frank Marshall and Kathleen Kennedy had purchased the property in 1993; and in the ensuing 13 years, it had attracted the attention of a number of prominent directors, including Steven Spielberg, Ron Howard and Spike Jonze. “I think Benjamin Button was the first property Kathy and Frank went after when they started their company, Kennedy/Marshall,” Ceán Chaffin commented. “It had been out there, in town, for a long, long time.”

Fincher had been intrigued by the project from the time he had first read an initial draft of the screenplay, written by Robin Swicord, in the early 1990s. “I thought it was a wonderful story,” remarked Fincher, “but I couldn’t imagine how it could be made, other than having different actors play Benjamin at different stages of his life. But even though I couldn’t imagine how to do it, I liked it and I kept an ear out for what was happening with it.” Ten years later, Fincher read a new screenplay, this one written by Eric Roth. “I thought that script was amazing; and, by then, I thought we were at least on the cusp of being able to do it.”

By the turn of the 21st century, a lot of time, money and energy had been expended toward realizing a photoreal, animated digital human character, both in the academic and entertainment realms. Some efforts had hit the mark better than others, but none had resulted in a completely convincing, organic and emoting human being; and none had crossed the threshold of the ‘uncanny valley,’ a term referring to the in-the-gut unease the average person feels when viewing artificial human beings, be they animatronic or computer generated. The best the movies had produced were stylized digital humans — such as those featured in *Polar Express*, *Beowulf* and *Final Fantasy* — or digital doubles that looked reasonably lifelike, as long as they were seen only in quick cuts and from a distance. What Benjamin Button required, and what David Fincher was proposing, was a much higher level of digital actor.

Less innovative and technological approaches to solving the ‘Benjamin’ problem had been considered, by Fincher and past directors, though only fleetingly. Aging an actor through extensive prosthetic makeups — à la Dick Smith’s masterful creations for Dustin Hoffman in *Little Big Man* and

Director David Fincher shot the film in New Orleans, often on minimal sets built in warehouses by production designer Donald Graham Burt. For the train station interior, Fincher shot on a set comprised of only a platform area, plus a few benches and light fixtures. Matte World Digital extended the set, creating an elaborate 3D environment that featured architectural dressing and detail from the 100-year-old Union Station in Washington D.C. To accommodate any number of different lighting scenarios in the 3D model, Matte World Digital rendered every light source separately, then combined them to exactly match the set lighting in each of the 29 station interior shots.

F. Murray Abraham in *Amadeus* — could not have carried the illusion, no matter how artfully done, given the character’s centrality to the story and significant screen time. “The problem with old-age makeup is that it is additive,” explained Eric Barba, “whereas the aging process is reductive. You have thinner skin, less musculature, everything is receding. There is no way to do that 100 percent convincingly by adding prosthetics. A heavy makeup wouldn’t be representative of what an aged Brad Pitt would look like. It would only be representative of what Brad Pitt in an old-age makeup looked like.”

A series of complex old-age makeups also would have required hours of application time, slowing down production considerably. Makeup artist Greg Cannom and his crew did design less-advanced age makeups for Pitt and supporting characters in the film; and even those minimal age makeups added weeks to the production schedule. “Putting Brad Pitt in makeup for four hours every day for the most extreme old-age stuff would have added a lot more time,” Fincher said, “and he would have been exhausted all the time. Even if we had been able to do an old-age makeup on Brad’s face, there was no way to make him four feet tall, as Benjamin is as a child — not without resorting to an electric knife and some procedures he wasn’t willing to undergo.”

Fincher had also rejected the notion of casting different-aged actors in the role. “David believed that there would be an emotional and visual roadblock every time the actors changed in the movie,” stated Digital Domain executive producer Ed Ulbrich. “He thought you would lose the thread of the movie, the sense of this being one person’s entire life, beginning to end. The power of it was going to be seeing one actor, Brad Pitt, at all these different stages of life. It had to be the same guy.”

“Brad was the first person to put it in real simple terms,” Fincher added, “which was: ‘Why would I want to play five years of a character’s life? I want a shot at playing a guy’s whole life.’ We decided we would have to go to child actors to play Benjamin when he looks 12 and younger; but by then, we felt we would have made the case that this was the same guy, and people would roll with it.”

Computer generated head replacement was the only way to realize a consistent character portrayed by a single actor, and Fincher discussed how it might be achieved with Eric Barba and other principals at Digital Domain as they collaborated over the years on various commercials, music videos and films. A commercial spot that would star the late Orville Redenbacher — returned from the Great Beyond to sell his popcorn — offered Fincher and Barba a timely opportunity to explore techniques for creating a lifelike digital character. “There was no way to performance-capture Orville himself, of course,” Ceán Chaffin observed, “and so they captured someone else playing Orville; but, in the end, the whole thing had to be keyframed. Even



Benjamin takes note of his increasing physical prowess in the bathroom of the old-age home where he is raised. A number of prominent directors had taken an interest in the Benjamin Button property since producers Kathy Kennedy and Frank Marshall bought it in 1993; but the obstacle of how to portray Benjamin at the various stages of his life, without using multiple actors or spending exorbitant sums on technological development, had proved insurmountable. After following the project for more than a decade – and convinced that visual effects technology could finally meet the show’s unusual demands – David Fincher garnered a greenlight from Paramount Pictures and Warner Brothers in 2006.

though it didn't turn out as we'd wanted, it was a great learning curve for us. We learned that we really needed Orville to re-create Orville, because there are so many subtleties that make up a person. If you have someone else performing as that person, it's not the same."

"On the Orville Redenbacher spot, we learned everything not to do on Benjamin Button," Fincher elaborated. "We learned that we needed to minimize the amount of keyframe animation that had to be done, because there are all these weird little behavioral clues that an actor is constantly using in his performance, and those things are like a behavioral fingerprint. Rather than try to copy that with animation, what I wanted was a process by which you could literally xerox an actor's performance onto a CG character. I wanted something that wouldn't have to rely on the interpretation of an animator."

By 2004, Fincher and Chaffin had yet to secure a greenlight; but Paramount and Warner Brothers were intrigued enough to underwrite a proof-of-concept test that would determine the fate of the project. For the test, Fincher commissioned a sculpture of actor Joel Bissonnette as an old man, and Digital Domain built a CG head model based on a scan of that sculpture. Fincher then shot Bissonnette performing a scene in which a very young but aged-looking Benjamin bangs a fork at a dining table, the first head replacement shot in the film. Using that performance as reference, Digital Domain animated the CG head and tracked it to Bissonnette's body in the scene.

"We had only five weeks to do that test," Eric Barba commented. "Fortunately, the character didn't have to talk or emote much, so we didn't have to do actual performance capture. We just animated him directly through the scene — but it was still a lofty goal. We had a team of people who put their hearts and souls into it, and we delivered a good test. When I showed it to Frank Marshall, he said, 'This is the most amazing thing I've seen since the first dinosaur test for *Jurassic Park*.'"



Fincher's approach to portraying the advanced-aged Benjamin, developed with visual effects supervisor Eric Barba and key personnel at Digital Domain, was to shoot actors wearing blue hoods with tracking markers on set, capturing an appropriate aged body performance. Digital Domain would then replace the on-set actor's head with a CG head, modeled from a scan of a maquette depicting Brad Pitt as an old man. The illusion required significant advancements in animation, rendering and tracking techniques, fleshed out over the course of an extended postproduction period.



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Studio reaction was also favorable. “We showed the test to Paramount,” Fincher recalled, “and they said, ‘It looks fantastic; but it’s still too rich for our blood, too expensive.’ And so I went off and did *Zodiac*, hoping they would change their minds.”

The prospects for the production remained uncertain over the next two years, with studio enthusiasm rising and waning depending on business climate and other factors. “There were several times when David called, and said: ‘It’s over. It’s not happening,’” Ed Ulbrich recalled. “He declared it dead more than once, and that was very difficult for all of us, but especially for David. This was a very special film, and to develop the material for that long and hone it and try to make it work, and then not know whether it was going to go or not... Directing a film like this was not for the faint of heart.”

Fincher and Chaffin made their case to the studios again after *Zodiac*, this time suggesting a budget that was relatively modest — especially for a film so innovative and technologically challenging that its projected cost under a previous director had been rumored to reach \$300 million. “During *Zodiac*,” said Fincher, “both studios saw that Ceán and I are very fiscally responsible. When we came back to them, we said, ‘Look, we think we can make this for X,’ and we suggested a real number. It wasn’t going to be ‘X plus \$40 million.’ We wanted to commit to a number; but the number had to be within the realm of reality. At that point, the conversation changed.”

One of the financial breaks that would enable the film to be made for a reasonable price was a tax incentive offered for productions shooting in Louisiana. The cost savings were appealing, but Fincher had doubts about New Orleans as the setting for the story. “It had been written for Baltimore,” Fincher noted, “but we sent a location scout down to New Orleans anyway, just to check it out. When he started sending us pictures, we really liked what we were seeing. So I called Eric Roth, and said, ‘Do you think this could be a New Orleans story instead?’ And he said, ‘Yeah — in fact, I think that could be better.’”

In addition to helping the production budget, the relocation of the story to New Orleans made way for the dramatic device of using Hurricane Katrina as a backdrop to modern-day hospital scenes in which a young woman (Julia Ormond) reads to her dying, aged mother Daisy (Cate Blanchett) from the diary of Benjamin Button. “Eric felt that we needed to allude to Katrina in some way,” Fincher explained, “because, if we didn’t, the audience would be wondering: ‘This is New Orleans? Is this pre- or post-Katrina?’ We thought it would be interesting to set this deathbed confession right in the middle of Katrina.”

Upon securing a greenlight in 2006, Fincher and his producers began official prep on the film, which included awarding the head replacement shots to a visual effects house. Despite Fincher’s long association with Digital Domain, and the company’s successful proof-of-concept test, due diligence demanded that the filmmakers explore other effects facilities. “We met with a lot of people,” Fincher recalled, “and everybody agreed that this was the next big thing to figure out. ‘We’ve figured out water, we’ve figured out hair — now we just have to figure out eyeballs.’ But some of the people we met with didn’t think we could do it for the amount of money we had. It wasn’t, ‘Can it be done?’ but ‘Can it be done for this price — and in this time?’ Kathy Kennedy always says, ‘When it comes to visual effects, it’s not about whether you can do it, it’s about whether you can do it in time.’”

Among the visual effects experts consulted was Dennis Muren, with whom Fincher had worked at Industrial Light & Magic in the early 1980s. Muren's advice was that Fincher pick 60 shots that he really needed, and commit only to those — a compromise Steven Spielberg and ILM had reached for the groundbreaking *Jurassic Park*, which had featured only 57 computer generated dinosaur shots. "Dennis said, 'Sixty shots is the number you can afford to do for the money you're spending on this movie,'" Fincher recalled. "But 60 shots just wasn't going to be possible. I knew it was going to take more like 350 shots, which is about where we ended up. We had to shoot this as if Benjamin was really there, as if he was any other actor, which is why I even did shots that were over his shoulder, with just his cheek showing a little bit. For this to work, I had to cover every scene just as I would if Benjamin actually existed."

In the end, Fincher and Chaffin awarded the creation of the head replacement shots to Digital Domain; and after a decade of emotional, if not official involvement, Eric Barba and his team set itself to the task. "We'd developed a very compelling proof-of-concept test," said Ed Ulbrich, "but that was only one shot. Now we had to consider how we were going to create a character that could sustain up to an hour of the movie, in extreme closeup, a character that could laugh and talk and make the audience laugh and cry. We had developed the basics with our test, but by no means had we solved the great mystery of creating a human character through computer graphics."

"As we started out on this," Fincher added, "there was a lot of nervousness about it at the studios, of course, a lot of anxiety. Everybody asked the question: 'Can you really do this? No, really, look me in the eye, David — can you really, really do it?'" Time would tell.

Principal photography on *The Curious Case of Benjamin Button* began in New Orleans in November 2006. Employing Viper HD cameras for digital capture, Fincher shot on sets erected in warehouses-turned-soundstages and at various locations in the New Orleans area. On the set were three actors, each one representing Benjamin at a different stage of aging: Peter Badalamenti played the smallest, most aged-looking Benjamin; Robert Towers portrayed him for subsequent scenes in which he appears to be in his 70s; and Tom Everett played the stronger, more erect Benjamin — the last head replacement Benjamin before the film switches to Brad Pitt in a subtle age makeup. Each actor wore a blue hood with markers to facilitate the tracking of the CG head to his body.

When Fincher had completed principal photography, he cut the movie to determine exactly which takes Brad Pitt would be performing to throughout the scheduled seven-day performance capture shoot. The performance capture setup was comprised of four Viper cameras, trained closely on the actor's head and positioned to record his performance from a variety of angles. "We captured him performing every head-replacement scene," said Eric Barba, "so that every moment of that performance would be driven by Brad Pitt. Benjamin's lips would move like Brad's, his eyes would move just like Brad's, every nuance of expression would be Brad's. That was the crucial thing to getting Brad to come across in Benjamin. It couldn't just be a likeness. We had to re-create his exact timings and mannerisms, the exact way his facial muscles move, the exact expressions he uses. All of that had to be in our Benjamin Button character."

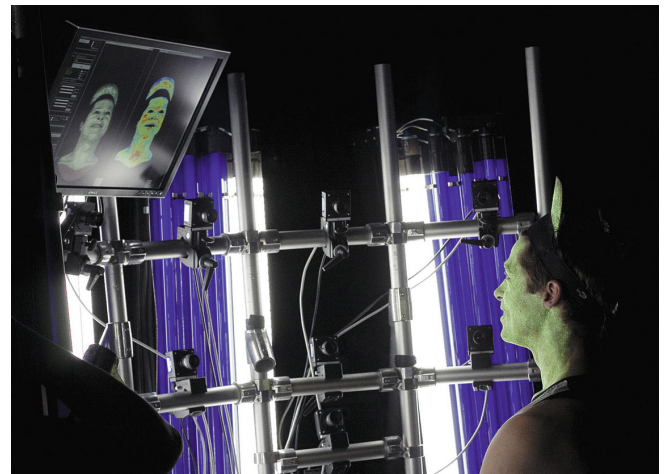
On the performance capture stage, Pitt and Fincher would watch a live-action scene on a monitor, and then Pitt would perform it, making sure his performance did not contradict what had been established in the on-set actor's body language. Immediately after a take, technicians would

position the image of Pitt performing the scene next to the live-action frames, allowing the actor and Fincher to assess the marriage of body and face performance. “When we put the performance capture next to the live-action,” observed Ceán Chaffin, “suddenly, instead of just an actor in a blue hood in the scene, we had Brad Pitt’s performance as Benjamin. It was very exciting to see that performance. He put so much thought into it, all the subtleties of playing someone who can’t physically move like a child, but who still thinks like one. He gave us these great moments of Benjamin playing with toy soldiers and making noises as he rolls his wheelchair, because he’s only six years old in his head. Brad delivered all of those childlike qualities, and yet still had the control to be still and be the observer that Benjamin is. And he did that acting all alone on a performance capture stage, without being able to interact with other actors or sets or anything. It was incredible.”

“I really enjoyed the performance capture shoot,” said Fincher, “and I know Brad enjoyed it, too. It was freeing. The scene was there, already cut, so we knew how long it was and exactly what it was going to be. And then Brad just did it. It was like looping the face. It was spectacular, and a lot of fun; but the process can be improved a lot. We’re not even in the infant stage yet with performance capture.”

Throughout the production period, a relatively small but dedicated crew at Digital Domain had been developing a pipeline for harnessing the performance capture and using it to drive utterly realistic CG Benjamin Button heads. Every member of that crew shared Eric Barba’s passion for the project — and his concerns. “It made us all very nervous, in a healthy way,” Barba commented, “but it really scared some people, and that made it difficult to staff the show at first. Some people thought it was going to be too hard, that we were setting ourselves up for failure — but I didn’t want those people on the show anyway! I wanted people who believed we could do it. So the first challenge was just finding like-minded artists and supervisors from within the company, and also from outside the company, to build a team of people who all felt as positive about our being able to do this as I did.”

Feeling positive did not mean that Barba had no angst about the task, however. Barba was, in fact, filled with angst as he contemplated the fact that, for Benjamin to work as a character, he and his team would have to make tremendous strides in three crucial areas: animation, rendering and tracking. “We were going to need a face system that could create realistic facial movement and could emote,” Barba said. “We were going to need realistic skin renders and lighting so that we could make the head look like it really belonged in every environment. And we were going to need perfect tracking of this CG head onto the live-action body. It was a very high goal; but what helped was realizing that replicating a human was a matter



Animation of the CG head was driven entirely by Brad Pitt’s performance, as recorded on a motion capture stage after Fincher had completed principal photography and cut the film. Four Viper high-definition digital cameras, trained closely on Pitt’s head and positioned to record his facial performance from a variety of angles, comprised the performance capture setup. After Pitt performed each cut scene, technicians positioned the captured image next to the liveaction frames, allowing the actor and Fincher to assess synchronization of the facial and body performances.

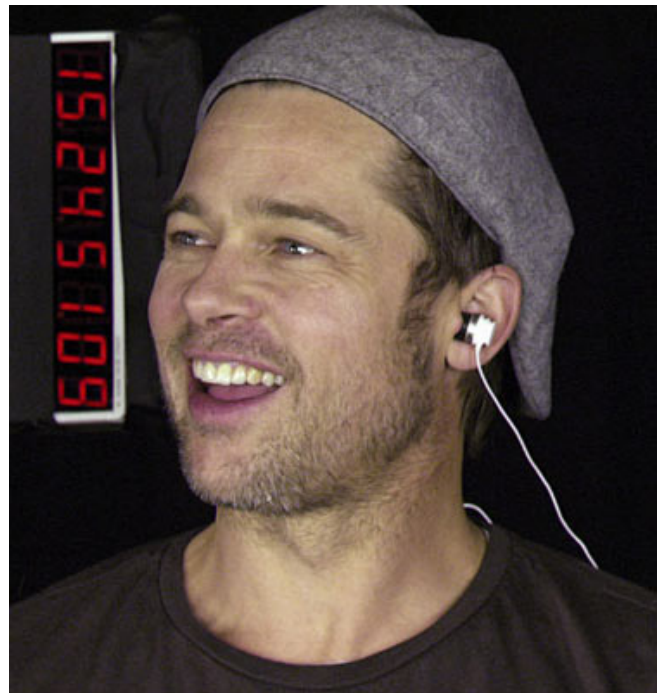
of breaking it down into individual pieces. We needed eyelashes, we needed lips, we needed teeth, a tongue and eyes. Once we broke it down into individual components, we could attack each component and figure out how to do it.”



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Only seven years old – but looking like a man in his seventies – Benjamin rises from his wheelchair and walks for the first time. Peter Badalamenti performed the scene on set, wearing the requisite blue hood with tracking markers. In post, Brad Pitt reenacted the scene on the performance capture stage, his face expressing Benjamin's struggle and joy as he takes his first steps. Animators at Digital Domain then used advanced image analysis tools to transfer Pitt's performance to a rough Benjamin head model. Special shaders and ray-traced displacement maps simulated photorealistic skin, complete with age spots, enlarged pores and other blemishes. The final head model included hair, generated through level-set technology in various thicknesses and colors, depending on Benjamin's age in a shot. Completed shots required seamless tracking of the head to the live-action body, achieved through on-set witness cameras that were synchronized to the main cameras and positioned to facilitate triangulation in 3D space.



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An artistic feat would precede the technical one. Working with age designs by Greg Cannom, makeup effects maestro Rick Baker and his longtime associate Kazu Tsuji created three lifelike maquettes depicting Brad Pitt as he would look in his 80s, 70s and late 60s. Kazu sculpted the looks over a lifecast of the actor; and from those sculpts, he and Baker created the finished, painted silicone maquettes. "These maquettes looked so amazing and real," said Ceán Chaffin, "when I showed a photo of one to Brad's agent, he thought it was Brad in makeup. At that point, I thought, 'Okay, we're doing well!'"

To obtain the best data for building the CG head models — without the softening effects of the outer silicone skin — Digital Domain had the maquettes scanned while in their plaster form. From those scans, CG artists built three different heads, modeling in aging details specific to each. "There were differences from one model to the next in the amount and severity of wrinkles around the eyes, for example," said Eric Barba. "There were differences in how gaunt the face looked, how the skin fell around the jaw line and chin. All of those things were modeled into the heads."

Digital Domain character supervisor Steve Preeg — a veteran of 2001's *Final Fantasy*, one of the first serious attempts at realizing digital human characters for film — designed the animation system that would translate the data captured from Brad Pitt's performance to the CG heads. The system took advantage of sophisticated image analysis technology that obviated the need for tracking markers used in previous motion capture setups. "Everything we'd ever seen done with tracking markers looked stretchy and rubbery," said Barba. "Markers just provide a sub-set of what the face is doing. The more markers you have, the more accurate the sub-set; but even with a very large number of markers, say 200, you still don't have data relating to what is happening in between those markers, and that explains the rubbery nature of it. We knew we were going to need a much better system for this."

"Hundreds of markers would have told us a lot about what the face was doing," Steve Preeg added, "but they wouldn't have necessarily told us what the character was feeling — and that's what we needed, a rig that would enable us to get emotion out of the character quickly. It was a huge

challenge. Not only did we have to make a rig that could produce believable, full-screen human head animation, which was already a big leap from what had been done before, it had to be something that we could do quickly, without having to wait three hours per frame just to see it. And it had to be a system that would allow David some flexibility to change things after the capture had been done.”

The animation system, branded ‘emotion capture,’ used computer image analysis to ‘read’ the performance capture and duplicate the facial movements and their timings on the CG head. “It involved volumetric capture of a library of Brad Pitt’s facial expressions,” said Ed Ulbrich, “which was then subdivided into thousands of ‘micro-expressions’ using Mova’s Contour system. That enabled Benjamin to express infinite subtlety using facial movements that were unique to Brad.”

The system also had a kind of manual override that enabled animation lead Matthias Wittmann and his team to correct the image analysis and animate on top of it through the manipulation and control of key shapes. “Image analysis figured out the timings of when the brows went up or when the mouth moved,” said Steve Preeg, “and all of those correct timings would be in the performance of the head. But that was just the starting point. We still had to determine if the face was doing what it was supposed to in terms of expression and emotion. Quite often, coming out of the image analysis, it would look like it was moving more or less the same as Brad Pitt in the performance capture, but the emotion would be a bit off. He might look angry or sad, when that wasn’t the emotion we were going for at all. Some shots were great right out of the image analysis, but most of them required some hand-manipulation.”

“As valuable a stepping stone as the image analysis was,” added Fincher, “it still left us with a lot of stuff to tweak because there is this deadening thing that happens. It tends to sandblast the edges off a performance, so you still have to go in and re-jigger that stuff; and that requires people who are artists in their own right. But there was never such a gap in the performance that it had to be entirely invented by that artist downstream.”

Sometimes animators needed to animate over the image analysis to correct a slight disconnect between what the on-set actor had done with his body and what Brad Pitt had done in his facial performance. “We got into a little bit of a sticky situation sometimes with eyelines not lining up exactly or the body performance not quite matching up to the motion of the head,” Eric Barba explained. “The body language would create one message, and Brad’s performance would create another; and when we put them together, they didn’t sync well.”

“It was amazing to discover the repercussions that the gross body movement had on the performance of the face,” Fincher affirmed. “One of my favorite shots in the movie is at the Thanksgiving Day dinner, and little Daisy says, ‘Isn’t it sad that turkeys



Ollin Studio treated film footage for a recurring gag in which a resident of the old-age home recounts the seven times he was struck by lightning. Fincher turned over to Ollin live-action plates, shot at 16 frames per second, which the visual effects team then massaged using both 2D and photochemical processes to create the look of very old, worn film footage. Ollin artists printed out all of the 1,000-some frames of the footage on paper, then soaked the paper in coffee to give it a yellowish hue. The artists macerated the paper, then shot the frames in intervals of ten seconds in direct sunlight and without proper

are birds that can't fly?' Another character says, 'I like birds that can't fly — they're so delicious!' And everybody laughs. Robert Towers, who was doing the body performance for Benjamin in that scene, tensed his shoulders, as if he was intaking breath and then exhaling for the laugh. When that movement was in sync with what Brad was doing facially, it worked and looked like a singular performance. But if it was off even by a frame, it looked freakish. It was very important that the facial performance closely follow the body performance."

registration to give it a washed-out, jittery quality. Discolorations applied digitally finalized the look.

With emotion capture, Digital Domain had developed a means of translating — if not quite 'xeroxing' — Brad Pitt's performance to its CG Benjamin Button. The second major hurdle was rendering and lighting the digital character so that he would look as much a part of the live-action environment as any other actor in the scene. "Lighting and rendering were especially important because of the kind of director David Fincher is," observed Eric Barba. "Each frame of the movie was like a piece of artwork; and to put our heads into those art-directed frames we had to replicate what the director of photography, Claudio Miranda, had done on the set."

"The problem was not only how to make realistic-looking human skin," affirmed lighting supervisor Jonathan Litt, "but also how to light the character as a cinematographer would, getting the face to sit in a beautifully lit environment. To do that, we couldn't just create spherical lighting, which is the norm. A sphere gives you infinite lighting, so no matter how an object moves around, you are still using the same lighting, just managed through rotation. For this, we needed the lighting to be exactly as it was when they shot the body actors on the set, so when we moved the head around between those lights, we would have proper fall-off and changing bounce colors."

To replicate the lighting in CG, a survey crew captured every detail of the on-set lighting environment. "We captured the full gamut of information existing in that physical world," said Litt. "The survey crew surveyed everything for every lighting setup — every light source, every bounce card, every scrim used on the set. They even captured what was behind the cameras, because that had an effect on the set lighting, too. We gathered all of that information, and from that we built a complete CG replica of the set and the lighting. That's been done to a certain extent; but what was unique to this show was the notion — spearheaded by CG supervisor Dan Abrams — of breaking up the environment into the actual lights that were on set, re-creating that setup exactly in 3D, and then having our compositors track the HDRI data onto the CG set pieces. It was a 2½D process that resulted in a 3D set in Maya, with high dynamic range textures on area lights and other types of geometry."



Benjamin visits a bordello, expressing his gratitude to the young woman who entertained him before taking his leave. One of the most challenging aspects of the head-replacement process was exactly matching the artful set lighting on the computer generated head. Rather than use spherical lighting — the most common approach to lighting CG characters and objects — Digital Domain crews surveyed every detail of the on-set lighting environment, including every light source, bounce card, scrim and set piece, so that they could re-create that environment exactly in the computer. The virtual lighting environment allowed for proper fall-off and changing bounce colors as the CG head moved within the live-action scene.

To augment the information gleaned from the on-set surveys, Digital Domain arranged to have the Rick Baker maquettes photographed on the ICT Graphics light stage at USC, which lights and photographs objects from every conceivable angle and outputs volumes of images and data. That light stage data was then used to generate rapid prototype lighting results in 2D, a compositing task overseen by Paul Lambert. “Using the ICT image database,” explained Litt, “the compositors could light the head in our compositing software, Nuke, without ever going to 3D. They would combine the different light stage angles to do this two-dimensional rough lighting of the head; then, in Nuke, they could project that onto the head geometry.”

“The compositors loved it,” said Eric Barba, “because instead of just being on the end of the pipeline, they were now driving the process, working directly with the lighters; and we got a good end result much more quickly than we could have otherwise.”

The thousands of images generated from the light stage sessions also served as visual reference for tuning skin shaders written by lead technical developer Tadao Mihashi. “There are ways of rendering skin just using the raw data acquisition from the light stage,” noted Jonathan Litt, “but we needed a more flexible approach; and so we used the images mainly as reference. We had a lot of photographs of the maquettes under set-type lighting, as well, and they looked completely human and real. So our rendering task was simple: Make it look like that. We also had the maquettes in-house the entire time we were working on this show, and having that concrete reference was key.”

As good as the maquettes looked, however, their silicone skins did not exactly match human flesh; and so they were not sufficient texture sources for the skin shaders. To gather more organic skin textures, Digital Domain conducted a high-rez still shoot of Brad Pitt, picking up pore detail specific to the actor’s face, and also shot high-rez closeups of some elderly people. “We couldn’t use too much of the texture from the older people,” said Barba, “because we didn’t want to age and discolor Benjamin’s skin so much that he was unappealing. But, at the same time, he had to look believable as an old man.”

Working in conjunction with the skin shaders were ray-traced displacement maps — created from scans of the maquettes, with additional painting in Mudbox by modeling supervisor Nick Lloyd — to create bumps, pores and other blemishes in the skin. “We created raw geometry,” said Jonathan Litt, “and then did displacement in Mental Ray, which is a ray-tracer. We worked with to improve Mental Ray’s underlying infrastructure so we could get ray-tracing, displacement, subsurface scattering and global illumination all working together.”

Rendering challenges were not limited to skin. As windows to Benjamin’s soul, the eyes, too, required complex renders, designed to silence the frequent — and largely accurate — criticism of digital human eyes as being lifeless and empty. “We knew that if we didn’t get the eyes right, it wouldn’t matter how good the rest of it looked,” said Eric Barba. “Without the eyes, it wouldn’t be Brad Pitt, and it wouldn’t be Benjamin Button.” Barba assigned CG supervisor Karl Denham to work solely on the eyes, first developing them, and then focusing on them for every head replacement shot. “All Karl did was work on the eyes, making sure every nuance of look and movement was there: how they moved, how they teared up, the details around the conjunctive area. Working on the eyes was Karl’s full-time job for more than a year.”

“What Karl did with the eyes was amazing,” Jonathan Litt added. “I’ve never seen an eye render like that. Every element — the amount of water in the eyes, the different layers of the skin, the red in the conjunctiva of the eye — was rendered out separately for control, and then the compositors layered those things together, shot by shot. Again, the compositing crew was more than essential to making it come together.”

The third leg of the head replacement triad was tracking. To marry the CG Benjamin head to the live-action body would require impeccable tracking, not only on an x/y axis, but in z-depth, as well. “The head had to sit on the spine correctly,” Eric Barba related, “because if it moved a little bit out of alignment with the spine, it wouldn’t have looked right, and it would have taken you out of the movie. That was one of the huge challenges we had to overcome early on. How do you build a system that will give you z-depth, will allow you to track in 3D space, but is simple and portable enough that it doesn’t take any time away from David on the set? Our 3D integration supervisor, Marco Maldonado, built a tracking system that enabled us to do that.”

To facilitate the 3D tracking to the blue-hooded performers on set, Maldonado and his crew set up additional Viper witness cameras, synchronized to the main-unit cameras. “There was an A and B camera for the primary photography,” said Maldonado, “and then we had two additional Viper cameras synchronized to those so we could triangulate in 3D space. As soon as we saw the first rehearsal, we would determine, ‘Okay, the extra cameras should be here based on what the main camera is going to be doing.’ All the cameras were in sync, and they were also timecode-stamped, which allowed us to line up images frame by frame. By having these synchronized, calibrated multiple cameras, we would not have to track to a single view. We’d have secondary views so we could see where everything should really be in 3D space.”

Some of the most difficult head replacement shots to track were those in a scene in which Benjamin sits naked in a bathtub. “I was there when they shot the body actor in the bathtub,” Barba recalled, “and David had the camera moving all over the place! That made me a little nervous about the tracking, because there were no clothes, nothing to help us connect our CG head to the live body — it was just skin to skin. Another director might simplify a shot like that, but David just went for it and was very bold. Normally, I’m the same way; but those bathtub shots made me very nervous. So I asked David if he could adjust the way he shot them just a bit, to make it less of a problem for us, and he did. I asked for those kinds of adjustments as little as possible on this show, but these bathtub shots were a very tall order. Compositing supervisor Janelle Crowshaw and her team showed amazing artistry and skill on shots like this.”

Of the 329 head replacement shots in the final cut of the film, many were tall orders, requiring significant reworking within one or more departments at Digital Domain. “David doesn’t like to be called a perfectionist,” noted Ceán Chaffin, “but he does perfect things; and so, some of the head replacement shots didn’t get approved for a very long time. One went all the way to version 100! There were a lot of things that had to be just right, and a lot of things that Digital Domain and David discovered about what looks real to the eye. We had to see a little bit of moisture in Benjamin’s mouth and on his lips when he talked. We had to see light shining through the top part of his ear. All of those little details and nuances had to be there.”



As a young man, chronologically, Benjamin finds work aboard the tugboat Chelsea. In addition to shooting some footage of a real tugboat on the Mississippi River, Fincher shot a full-size mockup against bluescreen. The mockup was mounted on a gimbal to execute banking and rolling moves. Asylum Effects generated synthetic water and backgrounds representing the Chelsea's ports of call, and then composited them with the bluescreen boat elements.



For scenes depicting the tug working the Mississippi wharfs and Eastern seaboard, Asylum artists thoroughly researched what the environments would have looked like in the 1930s. Asylum created photoreal Mississippi waters using proprietary software, Houdini, RealFlow's RF Renderkit and RenderMan. Buildings and dock structures in the harbors were built in 3D and in matte paintings. A shot of New York harbor featured period ships and the 1937 Manhattan skyline in the distance.

Head replacement shots cease approximately an hour into the film, some time after Benjamin, as a young man, leaves the old-age home where he has grown up and sets off to sea in the tugboat Chelsea. "Our last CG head is Benjamin appearing to look 67 years old," observed Eric Barba, "and then we hand off to Brad Pitt in a makeup designed to make him look 63. The first Brad-in-makeup shot is in the tugboat scene where the captain says to Benjamin: 'You're getting taller and bigger. Either that, or I'm drinking too much!' And Benjamin says, 'Well, you do drink a lot.'"



The Chelsea is conscripted for military service with the outbreak of World War II and engages a German U-boat in battle while patrolling the waters of the Atlantic. Digital Domain previzied the battle shots early in production, and modeled both the U-boat and the tug in the computer. Those assets were turned over to Asylum, where they underwent considerable remodeling as Fincher rethought the scene. Wide shots of the battle were all-CG, with computer generated explosions, smoke, debris and

In postproduction, Lola VFX digitally enhanced Greg Cannom's age makeups on Pitt and other actors, erasing seam lines, deepening creases, and adding shadows and bags, as needed. "We sent hundreds of shots out to be softened and retouched to make the makeup better," remarked David Fincher. "In film, that wouldn't have been possible, because we would have had to commit to cutting negative. With HD, we could up-rez material and look at it, and say, 'Hmm, that needs a little bit of work' — and we could go back in very easily and soften hair lines, wig lines, et cetera. We had instant control over little areas of the frame. I can't imagine having shot this movie on film, just because of the amount of material that needed to be massaged."

gunfire. As per Fincher's instruction, Asylum took great care to create tracer fire that was authentic to the time period.

At Lola, Flame artist Sean Wallitsch was responsible for massaging many of the shots featuring Brad Pitt in prosthetic age makeup. "The makeup work was very well done," observed Lola visual effects supervisor Edson Williams, "but it was still makeup and prosthetics, which just don't have the same texture or translucence as skin. So we helped it out with digital processes. We used mesh warps to distort the eyes and make them look older. We added droop that you just couldn't do with makeup. We did a lot of 3D facial tracking to place individual elements onto the actor's face — small wrinkles and other little nuances."

Lola finessed the extreme old-age makeup on Cate Blanchett as she appears in the hospital deathbed scenes, erasing flecks of latex, cleaning up makeup lines and making digital adjustments to the prosthetics to maintain their consistency from one day's shoot to the next. Lola executed more subtle age effects for scenes in which Daisy was to appear older than Blanchett, but not so old as to require prosthetics. "For those shots," said Williams, "we added sag digitally and did mesh warping to change the proportions of her face a bit."

Lola performed age-reduction for scenes featuring younger-looking Daisys and Benjamins, using digital techniques to shave years off of Cate Blanchett's and Brad Pitt's faces. "Consulting with noted plastic surgeon Dr. Andrew Frankel and using our techniques, we can make someone look about 25 years younger," said Edson Williams. "Our age-reduction technique is a 2D process done on the Flame or Inferno. We do virtual skin grafts, essentially, laying areas of good-looking skin over skin that has blemishes or wrinkles or shadows."

A scene that showcases Lola's 'youthening' effects is one in which Benjamin — looking like a young man of perhaps 20 — returns after a long absence to visit a middle-aged Daisy in her dance studio. "Our senior Flame artist, Casey Allen, worked on that scene," noted Williams, "and it had some of our toughest shots. We had about 15 closeups in the scene, and Brad Pitt had to appear 20 years younger than his current age. His eyes were the most problematic part of it. Some people, as they age, experience ptosis, which causes the flesh above the eye to protrude over the eyeball. Brad's eyes are predisposed to this condition, and you can see it even in the films where he was much younger. That made these shots really challenging. Casey had to model 3D geometry in Maya for his eye area, completely rebuilding the folds and creases of his eyelids."

Lola artists Brian Nugent and Chris Ingersoll implemented the technique for shots in which Cate Blanchett had to look younger than her real age. Some of the more challenging of those shots were in a scene in which the young-woman Daisy runs up the stairs of the old-age home, calling out

Benjamin's name and meeting him at the top of the staircase. "Cate Blanchett had to look younger and Brad Pitt had to look older — in the same shots!" Williams remarked. "We did cleanup of prosthetics around Brad Pitt's eyes and his neck; and then, on Cate Blanchett, we added definition to her jaw line, opened up her eyes and altered the texture around her neck, all to make her look younger. We also added a little bit of baby fat to her face, lifted the tip of her nose and thinned out her nostrils slightly." Surprisingly, the artists found that the actress' near-flawless skin made the shots all the more difficult. "To make someone look younger, we will normally remove the wrinkles from their face and clean up their complexion; but Cate Blanchett's face was so porcelain, anything we did to clean up the complexion or remove unwanted textures ended up looking completely fake. So, after doing our normal beauty work, we actually had to track texture back onto her face."

The subtlest of the Lola effects neither aged nor de-aged a character, but rather helped to maintain the continuity of the story. Lola artist Trent Claus tracked a crescent-shaped scar — the result of a wound Benjamin suffers in a World War II battle at sea — onto the right cheeks of Brad Pitt and the child actors who portrayed him later in his life. "Trent even tracked the scar onto the cheek of the baby Benjamin that Cate Blanchett holds near the end of the movie," observed Williams. "That was a real baby, and he had such featureless, perfect skin, it was difficult to track — there was nothing to track to! Adding the scar to the baby's cheek is a very subtle thing, but important because it helps the audience to believe that this is the same person throughout the film."

Lola contributed 269 shots to *The Curious Case of Benjamin Button*, each of them scrutinized under the fastidious eye of David Fincher. "David knows his shots," Williams concluded. "He'd come to look at our shots, and I'd tell him what was going on with them — but I was cheating because I had my notes right in front of me. 'Okay, we did this and this and this.' And Fincher, without any notes in front of him, would say, 'And you adjusted the right temple.' He knows every shot forward and back, and he knows exactly what he wants. We've worked with directors who say, 'I'm not sure what I want, but can you make the actor look 20 percent more glamorous?' 'Um, okay, 20 percent more glamorous... whatever that means.' But David Fincher gives you specific direction and input: 'The upper eyelid on the left side needs to come over an eighth of an inch. Okay, next shot.' He's amazing, and it was truly a pleasure to work with him."

Fincher brought that same eye for detail to synthetic environments created by visual effects supervisor Craig Barron, chief matte artist Chris Evans and all the artists at Matte World Digital — this year celebrating its 20-year anniversary. Barron and Fincher had worked together in ILM's matte painting department in the 1980s, and had remained friends ever since. "I love matte paintings," remarked Fincher, "and I learned about them from the best, because Craig Barron used to be my boss." Digital matte paintings extended minimal sets built on stages in New Orleans, transformed locations to appropriate time periods and, in some cases, produced all-virtual environments. "I always try to get at least 80 percent of a shot in camera; but a lot of times, what you get in-camera is just an amalgam of all the compromises that had to be made at a specific location. You're there, and you ask, 'Is there any way I could get up a little higher?' Or, 'Can we take down those satellite dishes?' And when the answer is 'no,' you realize that you're going to have to paint the top of that location and paint out the satellite dishes; and as long as you're doing that, you might as well do the sky and paint snow into the trees."

Matte painting effects helped to depict one of the earliest scenes in the film, a *World War I* armistice celebration that takes place the same night that Benjamin is born. As fireworks go off and jubilant crowds gather in New Orleans' French Quarter, new father Thomas Button (Jason Flemyng) reacts in horror to the birth of his hideously aged-looking son — an animatronic puppet — and the death of his wife in childbirth. "Benjamin's father runs through the streets of New Orleans, carrying this strange-looking newborn," said Craig Barron. "To show the whole city having this huge street party, we filled out the real crowds shot on location with our own employees. We shot them in our parking lot at night, standing or running around, waving sparklers and American flags, and then we added them to the streets and to empty wrought-iron balconies.

Compositor and matte painter Geeta Basantani added period fireworks that matched up with interactive set lighting, as well as background buildings with atmospherics and smoke to create a more celebratory mood."

Thomas Button winds up at a Mississippi River wharf area, where he contemplates throwing the newborn into the water — until a police officer comes on the scene. The scene was photographed at night, in an industrial area, with bluescreens positioned to back up the running actors, when necessary. Matte World Digital artists — with additional compositing help from Evil Eye Pictures — replaced modern city backgrounds with period buildings and water towers, and added docked riverboats, distant factories, smoke and green-tinted skies.

The film returns several times, in different time periods, to a train station inaugurated that same year. Production shot a New Orleans courthouse to represent the exterior of the train station. Matte World Digital removed the courthouse signage and added flags to the front of the building, matted in a number of Model-T cars to augment the few production had shot on location, tracked in people walking in the streets — more MWD employees — comped in a period industrial background, and lined the streets with telegraph poles and wires. For a shot of the station platforms, CG artist Morgan Trotter, an authority on trains, modeled a locomotive engine and additional cars, accurate to the last detail, to complete a single railroad car at the location.



Hydraulx contributed 73 shots to the film, including digital face replacements for sequences featuring Benjamin's lifelong friend, Daisy (Cate Blanchett), dancing with a Paris ballet company and on Broadway. Under the supervision of Eric Liles, Hydraulx artists carefully tracked Blanchett's face to that of a ballet dancer who stood in for the actress in the more demanding dancing sequences. Hydraulx also provided matte paintings, snow effects and digital street dressing for the film.

For the train station waiting room, designed by production designer Don Burt, Fincher shot only a minimal set on stage. “The set was just a few benches and a façade,” noted Barron. “To complete the shot, we added a 3D environment that had many architectural details from Washington’s Union Station, built over 100 years ago. Our imagined New Orleans train station included ornate ceilings and rows of windows with shards of light coming through them. We also added crowds of people.” Barron found inspiration for a decaying version of the station in the abandoned 12th Street train station in Oakland, California. “It is this dilapidated, otherworldly ghost of a train station, and it was perfect reference for us in showing the corrosive nature of time. This train station is almost like another character in the movie. We see it in 29 shots, from the beginning of the movie — on its opening day in 1918 — to the end, and it goes through a kind of character arc throughout the film: new, then run down, and then remodeled.”

Rather than create 29 digital matte paintings to represent the train station in different eras and at various stages of deterioration, Barron and his crew opted to build one 3D station model that they could alter and age as needed. CG artist Luis Hernandez worked on interior modeling and lighting for the 3D set, and digital matte painter Garrett Fry massaged the renders to add aging effects. “We used Next Limit’s Maxwell as our rendering software,” explained MWD visual effects producer Ken Rogerson, “which is used mostly for architectural visualization and product design. Architects might use it to show a client what a building will look like, based on accurate interior light bulb brightness and the effect of sunlight streaming through windows, et cetera. A lot of renderers are meant to just render an image quickly to give you a good approximation of lighting, based on someone’s best guess. But we wanted something that would mimic real-world lighting, that would be physically accurate; and so we adapted that Maxwell software to our pipeline.”



Lola VFX performed digital age-reduction techniques for shots of Daisy and Benjamin appearing younger than Cate Blanchett’s and Brad Pitt’s true ages. Using their 21/2D process, executed on a Flame or Inferno, Lola artists did virtual skin grafts, laying young-looking, unlined and unblemished skin over areas of the actors’ faces. To subtly shave a few years off of Blanchett for a sequence in which Daisy, now a young woman, returns to the old-age home to visit Benjamin after his return from the war, Lola defined Blanchett’s jaw line, opened up her eyes, altered the texture around her neck and added a bit of residual baby fat to her face.



Lola VFX performed digital age-reduction techniques for shots of Daisy and Benjamin appearing younger than Cate Blanchett’s and Brad Pitt’s true ages. Using their 21/2D process, executed on a Flame or Inferno, Lola artists did virtual skin grafts, laying young-looking, unlined and unblemished skin over areas of the actors’ faces. To subtly shave a few years off of Blanchett for a sequence in which Daisy, now a young woman, returns to the old-age home to visit Benjamin after his return from the war, Lola defined Blanchett’s jaw line, opened up her eyes, altered the texture around her neck and added a bit of residual baby fat to her face.

Using Maxwell, Matte World artists could quickly view their CG environment illuminated in any number of ways and from many different angles and sources. “We could render the effect of each light individually,” stated Craig Barron, “in separate layers, as a 32-bit, high dynamic range file, so we could combine and re-combine the interior lighting any way we wanted. We could see what our shot would look like if it was lit only from the windows, for example. We rendered all the possible lighting sources, and then mixed and matched them for each shot, using sliders to match the set lighting. It was computationally intensive, at first, because we had to put the effort into rendering all those different lighting schemes; but once we had that, lighting or re-lighting a shot went very quickly because we could add or subtract the calculated effect each discreet light had on the environment without re-rendering the whole scene. It was a good solution for the train station interior because we had multiple shots in the same environment, each with slightly different set lighting to match to.”

At the opening day ceremony in the station, clockmaker Gateau (Elias Koteas) unveils a backwards-running clock that he has built, a tangible expression of his wish to turn back time so that his fallen son may return from World War I, unharmed. The clock appears throughout the film, a metaphor for Benjamin’s reversed lifespan. Though the elaborate clock frame and stand were practical set pieces, the clock face and moving hands were digital creations, rendered into the frame by Morgan Trotter so that Fincher could avoid continuity problems when cutting together the train station sequences. “There was bluescreen material inside the clock frame under the glass,” explained Barron, “and our job was to insert the clock face and reverse-moving hands so we could make it read whatever time David wanted, regardless of how the sequences were later cut together.”

The clock features in the final image of the film, a long dolly shot that stops close on the old, elegant timepiece — now in storage in the train station basement — as it is overcome with Katrina floodwaters. “This was a signature shot for us,” commented Barron. “The water was practical, shot on a little basement set with boxes and the clock frame. The clock has a tarp over part of it, but at the end of the shot we see that the sweep second hand is still running backwards.”

Chris Evans did a painting illustrating the weathering and aging of the clock. “Pixel-fine details such as peeling paint, water stains and cracked wood brought realism to the scene,” noted Evans, “and we tracked those details onto the frame.” As the water in the basement rises, it seeps into the clock, causing the face to stain. “That’s a little detail that, if missing, would make the audience feel something was wrong,” said Barron. “They might not know exactly why, but it would seem wrong.”



Among the many CG environments contributed to the show by Matte World Digital was an aerial view of 1940s Paris. To gather reference for the shot, Matte World Digital supervisor Craig Barron spent a weekend in Paris, shooting digital still photography from a helicopter, 2,000 feet over the city. MWD artists used a flight simulator to choreograph camera moves at the 1,000-foot altitude Fincher had specified, ‘flying’ a virtual camera over a real-estate model of Paris. The final high-rez CG model of the city featured fully detailed buildings, art-directed clouds, and animated period cars traveling the streets around the Arc de Triomphe.

Another MWD setting the film returns to more than once is Thomas Button's country house on Lake Pontchartrain. Having made peace with his father's abandonment, Benjamin takes the dying Thomas to the lake house to sit on the dock and watch the sunrise, a reenactment of a fond memory from his childhood. Fincher shot the scenes at Lake Pontchartrain and surrounding woods; but there was no lake house at the location. "They built a strange pink box where the house would be," said Barron. "It was the same size and shape as the house we were adding in, and it was pink to make it easy to pull the matte from the surrounding green trees and grass." Digital matte painter Eric Hamel referenced a lake house design by Don Burt to build the structure, modeling it in 3D to accommodate camera moves.

For the sunrise dock scene, Fincher shot the actors on a lakeside partial dock, with a practical light source mounted at the end to illuminate the actors as if from the rising sun. "It was an actual incandescent light that dimmed up to throw interactive back-lighting on the actors' heads and hair," noted Barron. "Compositor Todd Smith took out that light and added our sky and rising sun element. We also enhanced the water. The lake was very flat and mirror-like the day they shot it, so we split in some water elements to give it a bit of life." Years later, Daisy and Benjamin return to the lake house, now dilapidated and overgrown with foliage. "We added a lightning storm to the shot of Daisy and Benjamin on the motorcycle, on their way to the lake house. For the house itself, we broke up boards and windows and made it sag a bit."

Matte World Digital created establishing shots for scenes following Daisy's dancing career — first on Broadway, and then in a Paris ballet company. Set in the 1940s, the establishing shot of the Flatiron Building and surroundings made use of textures and reference Chris Evans photographed in New York. Eric Hamel modeled and textured all the buildings of the computer generated city, adding signage, waving flags and drifting smoke. CG artist Dan Bornstein incorporated moving period traffic and people walking on the streets. An



Benjamin visits Daisy at the Majestic Theater in New York, where she is performing the famous ballet sequence in a production of *Carousel*. Matte World Digital artists started with a production plate shot at a theater in New Orleans, and then added the Chrysler Building and other period New York structures in the background to simulate 1940s Broadway. Matte World Digital also modeled and composited the marquee sign, complete with animated lights.



Benjamin visits Daisy at the Majestic Theater in New York, where she is performing the famous ballet sequence in a production of *Carousel*. Matte World Digital artists started with a production plate shot at a theater in New Orleans, and then added the Chrysler Building and other period New York structures in the background to simulate 1940s Broadway. Matte World Digital also modeled and composited the marquee sign, complete with animated lights.

establishing shot of Broadway featured the Chrysler Building and the old Majestic Theatre, with animated marquee signage by CG artist Glenn Cotter.

MWD created the same level of detail for an aerial establishing shot of post-World-War-II Paris. “What we brought to the shot was the lower altitude that David wanted,” said Barron, “which was much lower than you could really fly over Paris in a helicopter — ever since 9/11. With a complete CG environment, we were also able to give David a dramatic camera move and the just-after-sunrise lighting he wanted.”

Barron went to Paris for a weekend, rented a helicopter, and with a digital still camera took photographic reference from 2,000 feet over Paris to get textures for synthetic buildings. Back at MWD, artists used a flight simulator to work out camera moves at a lower, 1,000-foot altitude and to determine the specific aerial view of the city that was needed. “This simulator had a database of real estate models, including Paris,” Barron explained, “and we ‘flew’ it around Paris to choose our establishing shot. It was a very effective way to work out what David wanted to see, and get a fast approval before committing to building a high-rez CG model.” CG artist Michael Breymann detailed all the buildings and art-directed the clouds, while Morgan Trotter added cars traveling down the streets around the Arc de Triomphe. “These expansive, all-synthetic establishing shots are the hardest shots to do because you literally never finish them — you just stop working on them because you run out of time. Reality is so complex, you can always add more detail.”

Matte World Digital ended up contributing nearly 80 shots to the show. “Our shots were there to establish a location and create a mood that David wanted for the film,” said Barron. “They weren’t part of a slick, fast action sequence; and that was great for us. A lot of time you work on a shot and you put so much time and effort into it; and then, boom, it’s gone, and you think, ‘Gee, that was three months’ work!’ David makes the commitment to cool, long moments for the matte shots; and he has the confidence that the shot we do will be worthy of that much attention.”

Brought onto the project by visual effects producer Robin D’Arcy — a past Fincher collaborator and one who had followed the Benjamin Button project with interest for many years — Ollin Studio, in Mexico City, created CG exteriors for the deathbed sequences, adding environments and atmospherics outside the hospital room windows to indicate the approach of Hurricane Katrina. At the time Ollin joined the production, plates were not yet available, as Fincher shot the hospital scenes near the end of principal photography. “Without plates,” said Ollin visual effects supervisor Charlie Iturriaga, “we didn’t know how close we’d be to the windows. So we built a very high-



For a concluding shot of the train station interior, set in contemporary times, Matte World Digital exchanged many of the original 3D set’s elegant elements with more utilitarian ones, replacing the old backwardsrunning clock, for example, with a digital timepiece over the entryway. Matte World Digital also added modern arrival and departure signage, ATMs and video advertising to the interior set, and filled out live-action occupants with shots of MWD employees.

detailed exterior, replicating a couple of the streets in downtown New Orleans. We even created cars, complete with interiors.”

Ollin also began exploring how to create the effect of rain hitting the hospital windows in 120 shots, the downpour escalating in intensity with the passage of time. “Because of the number of shots,” said Iturriaga, “we had to come up with something that wasn’t too complicated. We didn’t want to do fully simulated CG water because we needed seven or eight minutes of material, some of it very closeup shots of the window. So we started playing with practical elements, and then moved to digital particles, making displacement maps so we could apply them to the plates. We used fans to hit glass with black Chinese ink, shot that over a white piece of paper, and used that as a matte. Then we mixed the particle and practical rain with our very high-resolution exterior. In Mexico, we often don’t have all the resources we need, so our artists are used to coming up with these kinds of solutions.”



The final image of the film is a long dolly shot that stops on the old backwards-running clock – now in storage in the train station basement – as it is overcome by Hurricane Katrina floodwaters. Fincher shot the clock frame on a small basement set plumbed with rising practical water. Matte World Digital tracked in weathering and aging effects on the frame, adding peeling paint, water stains and cracked wood. MWD artists also tracked in the backwards-running second hand and clock face, with an animated water stain moving up from the bottom as water overtakes the elegant timepiece.

Ollin also treated footage for a recurring gag in which Mr. Daws (Ted Manson), a resident of the old-age home, recounts the seven times in his life that he was struck by lightning. “It was very important to David that there was this comic relief episode completely outside the rest of the movie,” Iturriaga said, “and so he wanted it to look really old, very washed and worn by time. They gave us the live-action plates, which were shot on film so that David could shoot 16 frames per second, and we started exploring techniques to make it look like old material in an otherwise new film.”

What Iturriaga and Ollin artist Natalia De La Garza devised was a combination of 2D and photochemical processes. “There were about a thousand frames,” said Iturriaga, “and we printed every single frame of the material on regular paper, using a laser printer with really bad toner so that the blacks weren’t good and it was all very washed out. Then we macerated the paper, putting it in a jar of coffee so it became yellowish and worn and tearing it a little bit, frame by frame. In intervals of ten seconds, we shot that with a digital camera in direct sunlight so we’d have a change of lighting and color balance during the day. We also shot it without proper registration so that it looked like it was jittering. Then we applied digital discolorations and cleanups. The final result looked really good. No digital process could have given us the organic feeling of messing with a real material in the real world. Every frame was different, and David was really happy with it.”

Asylum Visual Effects created shots for a sequence depicting Benjamin’s life at sea aboard the tugboat Chelsea. In addition to shooting a real tug on the Mississippi, Fincher shot a full-size boat replica — mounted to a gimbal to effect bank and roll moves — on a bluescreen stage. Asylum’s task was to surround that bluescreen material with simulated water and environments representing the

Chelsea's ports of call. "We ended up with close to 200 shots," said Asylum visual effects supervisor Nathan McGuinness, "and every shot was a hard shot. All of the oceans and rivers were done in CG, and we had to create a lot of 1930s and 1940s environments in CG, as well. Our challenge was to make all of those feel as photoreal as the rest of the film."

Benjamin first finds work aboard the Chelsea at the docks of the Mississippi River. Asylum researched what that environment looked like in the 1930s, including the specific texture of the Mississippi waters. Asylum created that photoreal water environment using custom software, Houdini, RealFlow's RF Renderkit and RenderMan. "On top of that," said McGuinness, "we had to create all the structures and docks around the river, which we built in 3D and in matte paintings." After leaving New Orleans, the Chelsea travels up the eastern seaboard and into the Hudson River. Asylum built views of the 1937 New York skyline and populated the harbor with period ships. From the eastern seaboard the Chelsea makes port in Russia's Murmansk Harbor, where the water is covered in ice and snow. Don Burt designed the Murmansk matte paintings, which Asylum executed, generating snow in Houdini and using particle simulations to create a whiteout effect.

World War II breaks out while the tug crew is in Russia, and the boat is conscripted for military service. While patrolling in the Atlantic, the Chelsea engages a German U-boat in battle. Digital Domain previsualized battle shots early in production and modeled both the U-boat and the tug in the computer. Those assets were then turned over to Asylum, where they underwent considerable alteration and remodeling. The battle also required computer generated gunfire, explosions, smoke and debris. "The scene begins with a firefight between the two boats," said McGuinness, "and the realism of the tracer fire was very important to David. The way the tug fired upon the U-boat and how the bullets ricocheted — all of that had to be very carefully researched because it had to look like a real period gunfight, and not like something from a video game or *Star Wars*."

Severely out-gunned, the Chelsea's captain decides to destroy the U-boat by ramming it. "The actual collision is all CG," stated McGuinness, "including the tug. We opted to build the tug in CG rather than use the gimbal boat because it didn't have the movement it needed to sell the collision. We had to see the Chelsea speed up, and it all had to work with our water sims and our CG U-boat." The 24 all-CG shots in the collision sequence included crew members, stolen off the gimbal footage and tracked onto the CG tug.

Asylum worked on the film for eight months, an accelerated work schedule given the number of shots and the high level of detail and photorealism required. "You can't do anything heavy-handed with David," McGuinness concluded. "It all has to be very subtle and nuanced. There can be no exaggerated skies, no exaggerated waters — nothing is ever exaggerated for the benefit of a visual effect. Everything had to be exactly as it would be if David had been out there with his camera."

The final tally of shots contributed by the various effects houses to *The Curious Case of Benjamin Button* totaled approximately 1,200 — 300 of which involved all manner of digital fixes. All of the shots were 'air-traffic-controlled' by postproduction supervisor Peter Mavromates. "Because David is so strong in effects techniques," Mavromates commented, "he didn't need a production-side visual effects supervisor on the show. He just needed someone to keep an eye on all the vendors and make sure that stuff was coming in and going out. With just my digital ninja, Tyler Nelson, and myself and a small editing team, we were able to track, receive and deliver these 1,200-plus effects

shots very efficiently. What made that possible was the movie's digital capture. Without digital capture, they would have needed a very large team to do what our small team did."

Hardly a typical 'effects film,' despite its 1,200 effects shots, *The Curious Case of Benjamin Button* has nonetheless earned a place in visual effects history. Common wisdom had long held that a believable digital character, when finally achieved, would be the culmination of incremental improvements, the camera inching closer and closer to ever more convincing digital doubles. But Benjamin Button, created through a marriage of an actor's imagination and stunning technological breakthrough, is not a timid baby-step forward; rather, he is an Evel Knievel-like leap over the uncanny valley.

What is most striking about the work is its sheer audacity, the boldness with which David Fincher shot the character — in closeup, in long takes, naked in a bathtub, in bright sunlight. "David absolutely went for it," Ceán Chaffin observed. "I remember when we shot the Thanksgiving Day scene, when Benjamin is meeting Daisy for the first time. We were shooting day exteriors, and I was looking at that bright sun, thinking: 'Oh, my God, hard sun. Is this a good idea?' But David was absolutely fearless. He was also very collaborative. This has been a tremendously collaborative effort, and I think we all walk away from Benjamin Button having done our best work. The DP walks away with his best work. Digital Domain walks away with its best work. Benjamin Button is the best work any of us, all across the board, has ever done."

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Stuart Freeborn

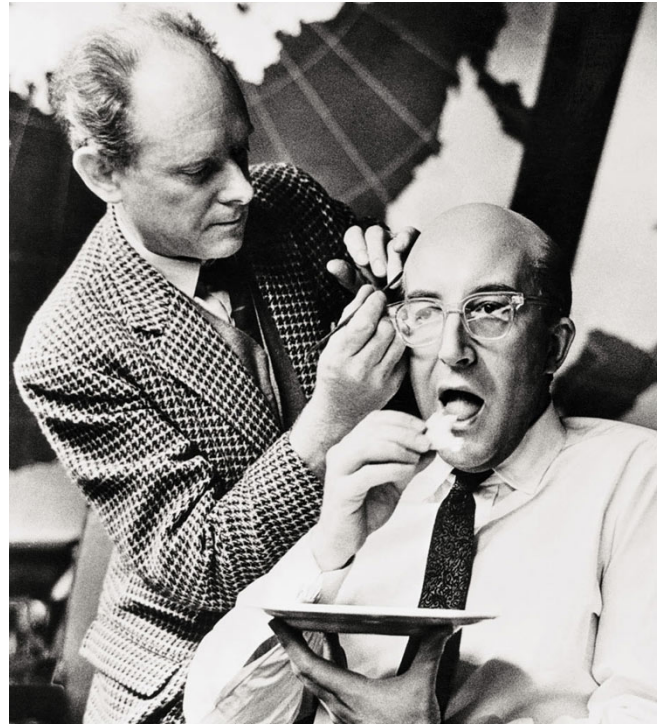
PROFILE BY MARK BURMAN

Born in 1914 in Leytonstone, England, makeup effects legend Stuart Freeborn was captivated by the movies when both he and cinema were in their childhoods. But his father, an insurance broker at Lloyds of London, had already mapped out a life amongst the ledgers for Stuart. “My father would take me up to his office, and say, ‘Soon you’ll be an office boy here,’” Freeborn recalled, “and I thought, ‘Oh, my God, I don’t want to do this!’ I was good at art. At school they would put my work up on the walls. That’s what I was best at.”



Captivated by movie monsters since boyhood, acclaimed makeup artist Stuart Freeborn first found entry into Britain’s film industry in the mid- 1930s, working with makeup great Guy Pearce. After a stint in the Royal Air Force during World War II, Freeborn contributed to David Lean’s 1947 film, Oliver Twist, creating an over-the-top Fagin makeup for a young Alec Guinness that stirred outrage and controversy among critics and Jewish organizations.

Freeborn left school at 14 years old, his mind's eye fixed on the monstrous appeal of *Frankenstein's* monster, Lon Chaney's *Phantom*, and particularly Mr. Hyde. Drifting through a succession of casual jobs, Freeborn spent his meager earnings at the theatrical makeup suppliers of London's Covent Garden. By night, as the rest of the house slept, he locked himself away in his bedroom to experiment with makeup techniques that were largely self-taught or gleaned from the few available books on theatrical makeup. Freeborn photographed the results with a jerry-rigged box camera he'd bought for two shillings, processed sepia matte prints in the family bathroom, and then sent them off to the film studios, hoping to land an interview. "I waited and waited — not a single answer."



Freeborn makes up Peter Sellers as U.S. President Merkin Muffley, one of three roles the actor played in Stanley Kubrick's apocalyptic comedy, *Dr. Strangelove*.

Undeterred, Freeborn began making the rounds of the British studios in person — and got a peculiar response. At each studio, after asking for the head of the makeup department, a studio doorman would check his name against a list and promptly throw him off the lot. "I thought it was extraordinary that I never got past a single doorman or had a single response to any of my photographs and letters." Still determined to see his work on screen, Freeborn joined the Beckenham Cine Society, one of many amateur film societies that sprang up in the 1930s with the advent of affordable Standard 8 cameras. "I started writing scripts with a lot of makeups in them — old men, Chinese characters, Jekyll & Hyde and Scarface. We'd show these movies on Saturday afternoons to relations and friends, and make just enough money to make more films."

At the age of 22, Freeborn noticed a newspaper article about Britain's newest studio complex, Denham Studios, the dream of Hungarian filmmaker and showman Alexander Korda. With seven stages and the largest electricity generating station in England, the studio complex quickly became a financial millstone that needed a constant stream of productions to balance the books. To meet that need, Korda imported the filmmaking elite of Europe, established a roster of upcoming contract players and Hollywood stars, and recruited Guy Pearce to head up his makeup department. Freeborn had no idea that Pearce was the intended recipient when he mailed out his sepia prints to 'Chief Makeup Artist, Denham Studios.' Remarkably, Freeborn soon received a letter from Pearce, inviting him for an interview.

Freeborn approached the gates of Denham fearing another rebuff. "They asked my name — and didn't throw me out! Guy Pearce told me to apply an old-age makeup to myself, and then they would film it." Freeborn's makeup was subjected to a full screen test; and just two days later, he was put to work on Rembrandt, with Charles Laughton, and many other films then in production, including *The Man Who Could Work Miracles*, *Things to Come* and *Elephant Boy*. "Guy Pearce took me

into a huge makeup artists room, put a pile of makeup on the table, and said, 'Just do what you've done on your photographs, and I'll be very pleased.' Before I knew it, there was an actor in my makeup chair — and I never stopped from that moment. At one point I was working on 11 films. Every stage and backlot was occupied."

Among the pictures was the extravagant *Knight Without Armour*, the first and only British film to star Marlene Dietrich. "Dietrich was very fussy about her makeup. She would watch the rushes and talk to the cameraman and analyze everything. She knew exactly what worked for her and for the cameraman." Dietrich, typically, would use highlights and key shadows to complement the single, high, key light on which she insisted. She would apply a pale line along the middle of her nose to minimize its turn up and a white line on the inside edges of her lower eyelids to emphasize the reflection of the key light. "I learned a lot of tricks from Dietrich that I used all the way to the end of my career."

The last notable film of Korda's reign at Denham, before his creditors closed in, was *The Four Feathers*. A.E.W. Mason's flag-waver set its tale of heroism amidst the ill-fated Sudan campaign of the 1890s, in which the British Empire suffered its first defeat by the Mahdi of Sudan and his 'fuzzy wuzzy' Hadendoa warriors. Back at Denham, the fuzzy wuzzies — so called because of their distinctive matted hair — were recruited primarily from London's own African population, presenting Freeborn with an unexpected challenge. "Many of them had vaccination scars which came up as keloid; and so they sent for me to fix them. I knew how to do scars using non-flex collodion, which had alcohol in it. When the alcohol evaporated, the collodion would sink — perfect for a scar when it was painted." Freeborn determined that the same technique could be used to 'sink in' a raised keloid scar. "I thought: 'I'll use that, and if it sinks in too much I can always put a bit of wax in it and bring it up. I watched the movie just the other night and couldn't see a single scar."

The Four Feathers was a patriotic boost to a country already heading towards a second war with Germany. In 1940, after working on the Technicolor fantasy *The Thief of Bagdad*, Freeborn volunteered for the Royal Air Force. He excelled in basic training, but an outbreak of Asian flu laid low his entire class of trainee pilots and threatened the life of the would-be air ace. "I very nearly died from a hemorrhage in the nose. I had hemophilia, but didn't know it then." Freeborn continued to lose blood and weight; and by the time he was sent home, his vision was severely impaired. A doctor suggested a radical idea for saving Freeborn's life — using snake venom to congeal his blood. "The doctor said to my father: 'It could kill him or save him. What do you think?' My father said, 'If it's the only choice, then use it' — and here I still am."

Freeborn was cured, but still too sickly to rejoin the RAF. Instead, he supported the war effort working as a draftsman in a factory that made precision aircraft instruments. Undergoing a six-month basic training in engineering, Freeborn again excelled. Switched from the draft board to the assembly line, he was charged with hand-picking a small team of engineers engaged in reducing the cumbersome radio control mechanism for anti-aircraft guns. The mechanical training would prove invaluable in the years to come.

British cinema enjoyed a golden era in the years during and immediately after the war, and Freeborn worked on many notable productions, including *Brief Encounter*, *A Matter of Life and Death*

and *Odd Man Out*, earning his first on-screen credit as chief makeup artist on *Green for Danger* in 1946. A year later, while working on the period piece *Captain Boycott*, Freeborn finally solved the mystery of his rejection at the gates of so many studios. Having hired six veteran makeup artists for additional crowd work on that film, he was disrupted from his duties by a gale of laughter floating down the corridor. "I flung open the door, and asked, 'What's the joke?' And they all replied: 'You are! We were all the chiefs of makeup at the old studios. You used to send us those photographs, and we got together and decided you were a damned sight better than any of us. So we told the studio gatekeepers to never let Stuart Freeborn in!' I was glad they kept me out because that made me push even further."

Freeborn would find himself pushed to the limits with David Lean's 1947 version of *Oliver Twist*, for which he created a controversial makeup for 32-year-old actor Alec Guinness, cast as the aged street crook, Fagin. To prepare, Guinness and Freeborn discussed the classic look of Fagin as depicted in the *George Cruikshank* illustrations that accompanied the novel on its first publication in 1838. Dickens' creation was instantly branded anti-Semitic by some — accusations that have forever dogged it — and Freeborn was sensitive to that issue as he developed makeup designs for Fagin. "I said to David Lean: 'All the Dickensian characters are caricatures, larger than life, especially Fagin. He's got to have a Jewish nose — but the drawings are over the top, illustrating a character with something much bigger than an ordinary Jewish nose. We don't want to upset Jewish audiences. What do we do?'" Lean's suggestion was to film the test two ways: once with the over-the-top, caricatured makeup, and again with a more toned-down look.

For the Cruikshank version of the character, Freeborn applied heavy wrinkles, a beard and eyebrows, eye bags and a large wax nose to Guinness' face. "I made his nose longer, gave him hollowed cheeks, dropped eyelids and wrinkled lips — anything that would make him look unpleasant. The next day I cleaned him all up, did a normal nose and a tidier beard. When we screened the two versions, the toned-down one looked just like Jesus Christ! Lean said: 'No way can we go with that. We'll have to go with the first version.'"

Despite a note of warning from Joseph I. Breen, feared administrator of the Production Code Administration, that a portrayal of Fagin offensive to a specific racial group or religion would meet with 'very definite resistance' in the United States, Lean went ahead with the exaggerated makeup. Fagin's great beak would prove to be not only a source of controversy, but a continuity problem. "In those days, false noses were all done with wax. I did that makeup 52 days, but not consecutively; and so keeping continuity wasn't easy." Halfway through production, Freeborn conceived the idea of creating a mold so that he could essentially stamp out identical wax noses.



Freeborn collaborated with Kubrick again on 2001: *A Space Odyssey*, for which the eccentric and demanding director needed makeups that would transform human performers into convincing ape-man specimens for the film's opening 'Dawn of Man' sequence. Initially engaged for five months' work, Freeborn spent two years toiling on the film, finally producing — after much trial and error — cinema's first fully-articulated creature head. Freeborn finesses a *First Man* sculpture.

Using a lifecast of Guinness, Freeborn modeled Fagin's nose in plaster and tried pressing the wax inside, with disastrous results. "It stuck to both sides of the plaster mold and ripped it apart." Frustrated, Freeborn took solace in the great British cure-all, a cup of tea. "The canteen gave me a mug of tea without a handle. It was too hot to pick up, so I poured milk into it — and it got hotter! I realized that pouring in the cold milk only pushed the heat outwards. It was colder in the middle, but hotter further out. That gave me an idea. I thought, 'What if I put the wax in hot water, put the nose molds in icy water, take them out and then press the hot wax in?' I would get the reverse effect of what had happened with my mug of tea: the cold would push the heat toward the middle, and the outer parts of the wax wouldn't stick to the plaster. I tried it, and it came out perfectly. From then on, I pressed out the noses and had them all floating in a goldfish bowl of water. All I had to do was take one out and put it on."

Oliver Twist was a critical and boxoffice success in the U.K., but elsewhere it received a stormy reception. There were riots in Berlin by the remnants of the Jewish community there, and it was effectively banned in the U.S. following protests from Jewish organizations and critics, one of which described Fagin as 'the worst caricature of a Jew ever depicted in an English-speaking film.' *Oliver Twist* would not be shown in the United States until 1951, and only then with 12 minutes of key scenes involving Fagin excised. It flopped, and it would be years before the full version would be seen in America.

There would be dozens more credits for Freeborn over the next two decades, including numerous Peter Sellers films, Walt Disney's television series, American and Italian productions at Cinecitta in Rome, and David Lean's *Bridge on the River Kwai*. The epic — and, by all accounts, wretched — *Kwai* shoot reunited Freeborn with both Lean and Alec Guinness in the jungles of Ceylon. Though grand in scope, the production had a far from grand budget, with producer Sam Spiegel unwilling to pay for extras to go to Ceylon. The only available extras to play the film's pale and starving prisoners were members of the European armed forces — who were too robust to look as if they were suffering from malnutrition — and local Singhalese, who were too dark-skinned to look sickly and pale. "With the European extras, we would paint in all the ribs, put shadows over the ribs and fleshy parts, and put highlights on the bone. On the Indian extras we reversed the highlight and shadow scheme." The other challenge for Freeborn was that, again due to budget constraints, he was not able to engage a team of professional makeup artists, despite the large numbers of prisoners that had to be made up for each day's filming. Freeborn chose inexperienced locals to act as makeup assistants. "For a long time, it was only me and this Indian crew. I chose people from art schools, and had them draw a skeleton to see if they knew enough about anatomy. I chose those who drew best."

The shoot for *Bridge on the River Kwai* holds far more painful memories for Freeborn than just working with an inadequate and inexperienced makeup crew. Sixty miles south of Colombo, a lorry driver, swerving while swigging on a drink, struck the car carrying Freeborn and the first and second assistant directors. Freeborn was catapulted through the roof to the sound of glass and crashing



The First Man heads were comprised of a rigid urethane underskull – molded to the exact facial dimensions of lead ape-man performer Dan Richter – covered with a thin foam rubber mask. To achieve articulation in the mask, Freeborn attached it to Richter's face using pieces of velcro, which resulted in the performer's lip and facial movements being transferred to the foam rubber piece.



Freeborn clowns around with his simian performers on the set of 2001: A Space Odyssey.

metal. “I was flying over the treetops; and then — whoompf! — a branch hit the back of my neck and nearly broke it. I woke up lying on a huge anthill, which saved my life. My spine was broken in two places. I lay there semi-conscious for four hours. I heard the rescuers, but I couldn’t speak and they couldn’t find me in the bush.”

Freeborn ended up in an English tea planters’ hospital where the critically injured first A.D. would die. Placed in a plaster cast, surrounded by a screen, Freeborn slipped into a coma. “One day I heard a little bit of noise. I was aware of somebody standing behind the screen. I strained my eyes and got a very vague glimpse. It was David

Lean. I thought, ‘My God, he has come all this way just to look at me and try to wish something.’ I felt it, from his mind to mine; and from that moment, I changed completely. The nurses said: ‘You have made the most remarkable recovery. We thought you were going to die.’”

Freeborn spent four months in the hospital. After convalescence, he quickly returned to work, earning 25 makeup credits in the course of the next decade.

There was little in that decade’s work to

dramatically test makeup skills forged in the frenzy of Denham Studios or engineering talents honed by war work; but that test finally came when Stanley Kubrick engaged Freeborn to join a production that would forever alter careers, lives and the movies. “I still have the letter from Stanley saying, ‘2001: A Space Odyssey is an interesting film makeup-wise — five to six months’ work.’ I spent two years — seven days a week, 12 to 18 hours a day — working on the film.”

A combination of mechanical know-how and technical improvisation, as well as decades spent studying the human face and anatomy, had primed Freeborn for 2001; and a stint the previous year transforming Peter Sellers into three distinct characters for Dr. Strangelove had primed him for working with the exacting taskmaster that was Stanley Kubrick. “On Strangelove, he was wonderful; but on 2001, he was a very different personality. There was trouble because he knew he was going to have to carry on for much longer than the five months he had initially said. It got difficult with all the departments; but I knew he could be a damned nice guy, and I carried on regardless. Whatever he said or did, I was going to stick it out. Our department was one of the few that went through to the very end.”

Shooting on 2001 began in December 1965, with the first makeup tests — aimed at realizing early man specimens for the *Dawn of Man* sequence — taking place in February 1966. In his initial tests, Freeborn, assisted by veteran makeup man Charles Parker, was striving to create a largely hairless hominid far further down the evolutionary chain than would eventually appear in the film. “We made all these high foreheads and big jaws, and we filmed for a week like that. They were supposed to be naked, and so Kubrick said, ‘I’ll shoot from the waist up.’ But 40 percent of shots in any film



In addition to masks, Freeborn devised physiquealtering suits for the 25 ape-man performers, each covered with human hair. Initially, Freeborn attempted to punch appropriate length hairs into the heads and suits using the broken head of a needle — a common technique innovated in Madame Tussaud’s famous wax museums. When the unusually soft foam latex — required to ensure flexibility in the articulated masks — caused the individual hairs to pop out, Freeborn devised a new method, inserting extra-long hairs via a hypodermic needle and then cutting them to length, an approach used to this day.

are full length, and he couldn't get away from that. So he said, 'Stuart, I want you to fix them, males and females, so we don't notice their crotches.' I had to have all the boys and girls lie down with their legs open so I could take casts of their crotches. Then I made these little plastic coverings and added hair to them — monkey codpieces." Kubrick shot the codpieced performers, but Freeborn was not at all happy with the effect on screen. "I told Kubrick they'd never be able to procreate like that — and that's the whole essence of the film. The only solution was to go back another million years or so to ape-men rather than man-apes."

Now looking to create a much more primitive, ape-like creature, Freeborn continued tests on performers, including diminutive British comedian Ronny Corbett. Keith Hamshire — the original Oliver in the London stage production of the musical and now a unit stills photographer — was also subjected to a lengthy makeup session and a series of rigorous tests conducted under 120-degree studio lights to simulate the high temperatures of South Africa, where Kubrick intended to film. When Hamshire collapsed and the makeup disintegrated in the heat, Kubrick and Freeborn opted to temporarily put aside the *Dawn of Man* sequence and move on to another makeup challenge: transforming 24-year-old actor Keir Dullea into the 120-year-old David Bowman, on the cusp of making the evolutionary leap into the Starchild.

Relying on an aging technique he had honed since his earliest days, Freeborn stippled layers of liquid latex to hand-stretched areas of Dullea's skin. "You have to do the stretch system of aging and stipple before you put your appliances on, otherwise everything goes wrong. You stretch the skin, stipple it and powder, stipple and powder." Freeborn also created an elaborate bald cap complete with pulsing veins. "This was the first time I'd used a foam rubber bald cap rather than a plastic one. I ran little tubes down his clothes so that I could stand behind the camera and pump the veins."

First Man, now conceived as *Australopithecus*, was still nagging away at Kubrick and Freeborn. The breakthrough finally came in October 1966 with the hiring of a young American mime artist, Dan Richter. Richter's audition — with the performer wearing only towels and a leotard — convinced Kubrick that physicality and gesture could convey the essence of the apes, but only if Freeborn could devise a makeup that was both convincing and sufficiently flexible to allow for a full range of movement.

An intense period of R&D followed, with Freeborn and Richter working closely together to test a constantly evolving design. What finally emerged was film's first fully articulated head — a head that could be put on or taken off in a matter of seconds, a critical element to filming a large cast of



Another makeup challenge on 2001 was transforming 24-year-old actor Keir Dullea into a 120-year-old David Bowman for the enigmatic conclusion of the film. Relying on an aging technique he had honed since the earliest days of his career, Freeborn stippled layers of liquid latex to hand-stretched areas of Dullea's facial skin. He also fashioned an elaborate foam rubber bald cap with a network of tubes that could be pumped from off-camera to create the effect of pulsing veins. Freeborn photographs Dullea in old-age makeup in the 2001 makeup room.

warring ape men. “I had to think of something entirely new. It would have taken a small army of people to apply prosthetics to all those actors. A separate head that could be taken on and off would be a tremendous breakthrough.”

Freeborn crafted a rigid urethane underskull — molded to Richter’s exact dimensions — with a thin foam rubber mask over it. “I had to find a way to transfer all the movement of his facial muscles, tongue and lips to the outside of the foam rubber mask. I did that by gluing velcro bits to the tops of his muscles, and then putting the negative side of the velcro pieces in the mask.” When Freeborn pressed the foam rubber to the performer’s head, it attached snugly via the velcro pieces, and Richter’s facial movements translated to the mask.

One of the tricky problems Freeborn had to solve arose from the fact that once the mouth and jaw of the mask had been forced open by the performer, they would not return to a complete close. “It would hang open a bit, both the jaw itself and the foam rubber on top of it, which looked a bit silly. Once the rubber stretched and loosened up, no matter what we did, the mouth would never snap shut again. Finally, I tried deep-field magnets hidden in the teeth, so that when the elastic band began weakening, the magnets would take over. If the magnets were flat, facing each other, it was a helluva job for the performers to break the magnetic field; and so I tip-tilted them slightly, which made all the difference.”

Essential to the believability of the mask was the facial hair and beards of the ape men. Favoring human hair over artificial monofilament, Freeborn painstakingly inserted each hair using the broken head of a needle, a technique borrowed from Madame Tussauds; but each time he inserted a hair, it would pop out, due to the extra-soft quality of the masks’ foam rubber. “To open the masks, I had to make the foam rubber softer than usual so it would stretch accordingly. The foam was so weak, and the hair so strong, it popped out.” Freeborn awoke in the middle of the night with a solution, which was to use a hypodermic needle loaded with longer hairs that could be cut to length afterwards. “I could push the needle through with the hair in it and it would only make a pinprick. Then I would pull out the needle; and because it was only a pinprick there was enough pressure to keep the hair in. I bought a load of hypodermic needles, tried it, and it worked.”

By the end of February 1967, both the mask and a physique-altering, hair-covered ape suit were ready, and Richter was put through a series of dynamic movement tests to ensure Freeborn’s creations would hold up in action scenes. However, due to the complexities of assembling, training, body casting and fitting another 25 ape men, shooting on the *Dawn of Man* sequence would not begin until the following October. In the interim, Kubrick — inspired and encouraged by the success of Freeborn’s designs — wrote a new *Dawn of Man* scene in which a baby ape would suckle from a mother’s breast. “I had to model practical foam rubber breasts so that the babies could actually suckle. I went through my books of monkeys, looking for monkeys in milk to see the shape of their breast and the color of their nipples.” To portray the suckling infants, Freeborn planned to make up two baby chimps provided by Mary Chipperfield, an animal supplier to films. “Baby chimps have that pink face before they get older, and they have smaller ears, but I thought I could make them up to match our monkeys.”

Freeborn and his wife Kay bonded with the baby chimps, Johnny and Timmy, carrying them around like real infants and slowly acclimating them to the makeup application process. “We got them used to the makeup, and they would be patient while we made them up; but when we finished, they would run to each other and start licking the makeup off. We had to smack their bottoms each time they did it, and by the fourth time they remembered and stopped doing it.”



More problematic was getting the baby chimps to suckle from the fake breasts, which had five little holes in the nipple, and a sac that Freeborn filled with a special milk formula via a very large syringe. “The biggest job was persuading the chimps to suck from these monkey teats. They didn’t want to know about foam rubber tits! I put special tastes and smells in the foam rubber that would attract them. Finally, after changing the flavor, I got them to suckle.” When it came time to shoot the suckling scene, Freeborn loaded the breasts with the milk formula, and sent the performers to the set. Once there, however, Kubrick decided to first shoot some fighting scenes. “Suddenly, during the fighting, the milk formula separated and started shooting out of the nipples! Kubrick went mad — ‘Send ‘em all back to Stuart Freeborn to fix ‘em up!’ I had to make a whole new batch in very little time; but looking back, it was hilarious.”

As ‘creative supervisor of makeup and special visuals,’ Freeborn worked on Richard Donner’s 1978 Superman and its two sequels, starring Christopher Reeve as the Man of Steel and shot at Pinewood Studios outside London. In addition to designing subtle cosmetic makeups to help distinguish Superman from his alter-ego, Clark Kent, Freeborn made life-casts of the principal actors to create dummies used in aerial sequences and others in the films. Freeborn attends to a completed Christopher Reeve head.



In 1976, Freeborn started work on Star Wars, his main task being the creation of Han Solo’s 200-year-old sidekick, Chewbacca. Freeborn based his first clay model of the character on a production sketch by artist Ralph McQuarrie, then remodeled it when George Lucas suggested he incorporate both canine and feline features into the Wookiee’s head. The final Chewbacca head was fully articulated, equipped with more sophisticated versions of mechanisms Freeborn had developed for 2001’s ‘Dawn of Man’ characters.

With his inventive *Dawn of Man* characters, Freeborn had joined ranks with Dick Smith and several other makeup artists who were pushing the craft into new realms, blurring the line between makeup and special effects. And so, it was no surprise when a young George Lucas sought him out in the summer of 1975, while Freeborn was at work on the hellish mechanical hound of *The Omen*. “This young fellow came in and started walking around my lab, picking things up. I thought: ‘He’s got a bit of a nerve walking around without asking me.’ Finally he comes up, and says: ‘My name is *George Lucas*. I’ve written a script for a film called *Star Wars* and I have a sequence in a cantina where a lot of people from different planets meet. I want the creatures to be interesting and ugly. I haven’t found anybody yet who can give me what I want, and your name has come up several times. Have you got things to show me from home? I’ll come back tomorrow.’ Suddenly, I thought he wasn’t such a young nuisance anymore.”

Freeborn started work on *Star Wars* in January 1976, his principal task the creation of Chewbacca. The working draft of the script described the 200-year-old Wookiee as ‘a huge, eight-foot-tall, savage-looking creature resembling a gray bush baby monkey with baboon-like fangs.’ A production sketch by Ralph McQuarrie guided Freeborn’s hand while Lucas pondered the final look of the Wookiee’s face. “Lucas said: ‘I was thinking he might have something like a dog face. Can you show me what you have in mind?’ I modeled it in clay, and the next morning he looked at it, and said: ‘Yes, yes, but I was looking at my cat last night, and I thought we should incorporate cat qualities.’ So I remodeled it to include both dog and cat types of features, and when *George* saw it, he said, “That’s it!” Freeborn proceeded to make the Chewbacca head, incorporating mechanisms he had developed for the *Dawn of Man* characters.

With the completion of Chewbacca, Freeborn and a crew of six began producing creatures for the cantina sequence. He had developed a dozen creatures when he was overcome by PVC fumes and had to be hospitalized. “I was intent on using chemicals and materials I had never used before; but I hadn’t realized how subtle PVC’s toxins were. It was a cumulative thing. I was all right for a few years, and then I collapsed. That put me out for a little while.” Rick Baker and Phil Tippett ultimately produced bug-eyed Benny Goodmans and other notable denizens of Mos Eisley for the cantina sequence, completed in the spring of 1977.



Lucas and Freeborn engaged a seven-foottall hospital porter named Peter Mayhew to portray the irascible Wookiee in the articulated head and a shaggy handpunched fur suit.

By then, Freeborn had begun his long association with the *Superman* franchise, the first two films of which were being prepared back-to-back under the direction of Richard Donner at Pinewood Studios. As ‘creative supervisor of makeup and special visuals’ Freeborn helped to define *Superman*’s dual nature through subtle makeup applications on actor Christopher Reeve. “For *Superman*, I did a lot of highlights on the jaw line to give him a much stronger jaw. I also strengthened other bone structure. For Clark Kent, I shaded the jaw down so it didn’t have the same strength of bone structure. It made quite a difference on the screen.”

Freeborn segued from the *Superman* films to *The Empire Strikes Back*, for which he created his most complex character — Yoda, the wizened, green hermit of Dagobah. “For the first time, this wasn’t makeup on a human being, it was a creature that was only two-feet-six-inches tall.” Preproduction sketches by Joe Johnston and Ralph McQuarrie had presented Yoda in a variety of guises, from a blue gnome to an elegant, somewhat ethereal elder. “Lucas couldn’t make up his mind, and so he let me choose. I chose one, and then worked out the detail as I went. I wanted to put scales on the top of his head for technical reasons, to hide join lines.” Other ideas came to Freeborn when he studied his own face in a mirror. “I thought I could use some comic aspects of my face — the little turned-up nose, some bumps here and there. Then I thought about this character’s intelligence, and I picked up a print of Albert Einstein.” Freeborn combined elements of Einstein’s face — such as the wrinkles around his eyes and forehead, and a lip that re-created the shape of the genius’ mustache — into the Yoda design.

To allow freedom of facial expression, Yoda performer Frank Oz had insisted that the puppet have no jaw; and that, too, added to Yoda’s wizened look. To ensure a perfect fit between puppet and puppeteer, Freeborn modeled Yoda’s mouth area directly on top of Oz’s hand, sculpting the top lip on Oz’s first two fingers and the bottom lip to fit around his thumb. Freeborn continued to sculpt, working backwards from the lips to the head. The clay sculpt was then carefully sectioned for a series of molds: a three-part mold to create the foam latex skin; a second mold — made from a plunger of the first and the cast of Oz’s arm — which would be used to create the fiberglass and polyurethane skull; and separate molds for the ears, hands and feet. The torso was constructed from a one-inch-thick sheet of flexible polyurethane foam, cut and glued to create the body shape and keep weight to a minimum.



*Freeborn’s most complex character – first created for *The Empire Strikes Back*, in 1980 – was the diminutive Jedi master, Yoda. Choosing an appealing design from among many presented in sketches by Joe Johnston and Ralph McQuarrie, Freeborn detailed the character with scales intended to hide foam rubber seams. Freeborn also incorporated features from his own face and that of Albert Einstein – including wrinkles around the eyes and a lip that re-created the shape of the scientist’s mustache.*

Though Oz would perform the character's mouth movements and gross body movement, some articulation — such as that for the eyes — relied on mechanisms and cable controls. For the eyes, the upper part of the skull was hollowed out to accommodate a brain-shaped brass mechanism, operated by a hand-control but designed to allow Oz's hand to pass through so that he could operate the eyebrows. "We put in as many movements as possible — top lid, bottom lid and eyebrows — to create a whole range of expressions. Everything was designed to make it live as much as possible."

In addition to the fully articulated Yoda, Freeborn built several other versions of the little *Jedi* Master for specific sequences. A radio-controlled Yoda in a backpack served scenes in which Luke receives his Dagobah training. For a scene in which Yoda runs around a tree trunk, Freeborn fit a Yoda head onto a little person. Because the performer was still double Yoda's size, the construction crew built a double-scale tree trunk for the scene.

Yoda was the pinnacle of a life in makeup, a career that took Freeborn from the lips of Marlene Dietrich to the movies' first animatronic character. For the half century prior to his last screen credit — the 1990 television movie, *Max and Helen* — Freeborn had been makeup's renaissance man, equally at home beautifying a star or pioneering breakthrough techniques. Until recently he would guide visitors through his makeup shed of delights, its narrow confines crammed with Wookiee teeth, ape masks and the severed arm of Luke Skywalker. Now his collection has been scattered amongst museums and collectors, and the 94-year-old Freeborn lives in a modest bungalow in the English countryside. A bust of Yoda, placed almost out of view, is the only clue that he has been Britain's outstanding makeup artist of the 20th century.



From his sculpture, Freeborn created a Yoda puppet that was brought to life by performer Frank Oz. Though Oz controlled the character's mouth and gross body movements, Freeborn fitted the puppet with numerous mechanisms and cable controls to create a range of facial expressions. In addition to the fully articulated Yoda, Freeborn built a radio-controlled puppet in a backpack for scenes in which the Jedi master trains the novice Luke Skywalker. In terms of both technical sophistication and artistry, Yoda represented the pinnacle of Stuart Freeborn's 55-year makeup career.

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